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ABSTRACT

This set of 16 laboratory activities is designed to illustrate the life cycle of Brassicae plants from seeds in pots to pods in 40 days. At certain points along the production cycle of the central core of labs, there are related lateral labs to provide additional learning opportunities employing this family of plants, referred to as "fast plants," at each particular stage of life. A flowchart of the activities provides the teacher with the sequence through which the students examine: the seed; planting; germination; plant thinning; photosynthesis; nutrients and the seed micro-development; vegetative development; the effects of gibberellic acid, light, and gravity on growth; floral development; pollination and bud removal; and seed and pod development. Student worksheets and corresponding teacher's guides are provided for each laboratory experiment. A glossary of 194 terms used during the experiments is provided. (MDH)

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BEGINNING PLANT BIOTECHNOLOGY LABORATORIES
USING
FAST PLANTS

ORGANIZED BY
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The following set of laboratories are built around the FAST PLANT resources developed by the University of Wisconsin team headed up by Dr. Paul Williams. FAST PLANTS are a family of Brassicae plants, Rapid Cycling Brassica Rapa, That go from Seed in the pot to pods ready to harvest and replant in 40 days elapsed time. Many of the labs represented in this lab pack were developed by Dr. Williams team and fine tuned by me based on my experiences running them with my students. Wherever possible I have integrated the use of BOTTLE BIOLOGY recyclable materials for more commonly used laboratory apparatus. If you have the lab tools use them, otherwise the pop bottles and plastic bags suggested by Dr. Williams and myself seem to be more readily available and work admirably.

The seeds and supplies referred to in the laboratories are available from Carolina Biological Supply in their regular product catalog under FAST PLANTS titles.

CAROLINA BIOLOGICAL SUPPLY PRODUCTS USED IN THIS LAB SERIES

Wisconsin Fast Pant manual	15-8950R
Growth and Development Kit	15-8702R
Anthocyaninless Seed	15-8812R
Rosette Brassica rapa Seed	15-8815R
Variegated Brassica rapa Seed	15-8820R

The purpose of these lab packs is to provide a set of lab instructions and work sheets that present consistency of both presentation and results for both students and instructors. Once the new learners get past the obstacle of objectives there is an exciting body of new knowledge and experience awaiting their discovery. Never before has such a large body of experience in the plant kingdom been available over such a short period of time. These labs are designed to make each new lab experience consistent with the last presentation.

There is a central core of labs that concern themselves with the learning that accompanies the production of the next generation of Brassica seeds. Non of these labs require more than a day to a week of time to harvest all their results. Any one of these labs can be performed by itself with a little plant generation preparation by the instructor ahead of time. The Instructor can run all the central core labs ("Observing the Rapid Cycling Brassica Rapa") consecutively if he/she so chooses and have a great Botany unit. The labs with fit your time units and the days required for plant production are remarkably consistent.

At certain points along the production cycle of the central core of labs there are related lateral labs that provide additional learning opportunities that employ the FAST PLANTS at that particular stage of life. These labs will again function perfectly as stand alone experiences or may be integrated as optional labs or extra credit opportunities. They usually build on the central core lab experience but in some cases might be substituted for the central core. See the Flow chart on the next page for a visual interpretation of the central core labs and their lateral lab experiences.

If use of these labs doesn't generate some better ideas about the use of the FAST PLANT teaching tool I will be genuinely disappointed. Read on McDuff, and may the force be with you!

SE 052523

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NAME_____
DATE_____

MOTHER'S CONTRIBUTION, THE POD AND SEED

NAME_____
DATE_____
SEED ID_____

Fast Plants (*Rapid Cycling Brassica Rapa) have been developed over a 20 year period to consistently go from seed in the ground to seed ready to plant in 40 days. This provides us with a unique opportunity to participate in the development of a plant life. Like you, this life form has a number of very specific requirements necessary to flourish and complete it's mission in life. You will have the opportunity to provide those requirements. The class will provide the materials, all you have to provide is the responsibility. Most of the changes in this life form as it grows are going to be radically obvious a few more subtle (especially to the new plant breeder, you). We don't want to miss a single fascinating aspect. The following work sheet has been developed to help direct and organize our observations. It progresses *chronologically from planting day to harvest day. There is going to be a consistent flow of laboratory activities (things to do) and observations (things to see and record). These exercises must be accurately accounted for two basic reasons. 1) To most critically compare earlier activities and observations with current developments and 2) To accumulate all the pieces necessary for successful completion of your final report. There are going to be questions that you don't have an immediate answer for. Ask, you might get an answer. Observe, measure, compare and discriminate and you will get an answer.

DAY NUMBER Planned Actual | ACTIVITY AND OBSERVATION | RECORD/MEASUREMENT

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0 ____ MOTHER'S CONTRIBUTION, THE SEED POD AND SEED.

At some point prior to your current experience some little RCBr seed was provided with the necessities to reproduce itself and you are about to be the beneficiary of it's life consuming efforts. Here's what you are going to do with your inheritance.

LABORATORY ACTIVITY

1. Get a *RCBr seed pod from the instructor.
2. Using the RCBr POD LABORATORY WORKSHEET to help identify pod pod parts perform the *quantitative measurements required and record your answers on that work sheet and in the spaces provided in the right hand column of this paper.
3. Record the length of the seed pod from receptacle to stigma — mm Length_____
4. Record the number of seed in the following categories:
   - TOTAL number of seed in the pod — TOTAL seeds_____
   - Number of seeds with dark seed coat — Dark Coats_____
   - Number of seeds with light seed coats — Light Coats_____
   - Number of shriveled seeds — No. Shrivel_____
5. Do the Seed Pod mount exercise on the RCBr POD WORKSHEET and label the pod parts as directed.
6. Hand in the RCBr POD LABORATORY WORKSHEET.

LABORATORY OBSERVATIONS

1. Do all the seeds in your pod look "exactly" the same? Why?

_____

_____

2. Why were the seeds attached to the placenta?

_____

_____

* Indicates a word that may be found in the GLOSSARY OF TERMS in the back of the lab sheets.

NAME_____
DATE_____

DAY NUMBER Planned	Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT
		LABORATORY OBSERVATIONS	
0	___	3. Were the seed coats developed by the pod (mother) or the seed?	
		4. What would be the equivalent of the pod in animal reproduction physiology and how are they similar?	
		5. What might answer for the "shrivel" found in some seed?	
		6. What are your other observations?	
		7. Other questions for consideration. Is there a *correlation between seed coat color and plant color? Do shrivel seed *sprout? Is seed coat color heritable? Is there a relationship between seed coat color and plant strength? Why is there air?	

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RCBr POD LABORATORY WORKSHEET

NAME_____
DATE_____
SEED ID_____

DAY NUMBER Planned Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT

REQUIRED EQUIPMENT AND MATERIALS

1. A Rapid Cycling Brassica rapa seed pod, complete with seeds
2. A sharp blade (razor, knife, scalpel)
3. Scotch tape, magic mending tape or similar clear adhesive film.
4. This work sheet and the "OBSERVING THE RCBr LIFE CYCLE" work sheets.
5. Hand lens or similar magnifying tools might be helpful.
6. Tweezers can be helpful.

0 ___

LABORATORY ACTIVITY

1. Get a *RCBr seed pod from the instructor.
2. Record the length of the seed pod from receptacle to stigma mm Length_____

STYLE

CARPELS

RECEPTACLE

3. Using a sharp blade or finger nail, carefully separate the *carpels along the ridge that forms the natural connection of the two. Be careful when separating the carpels. We want to carefully examine the tissue and seeds found inside as undisturbed as possible. Tape the carpels to this sheet in the space provided immediately below and label them.

Next observe how the seeds are attached to the tissue of the *placenta found inside the carpels. Is the relationship between this tissue and seed duplicated in other life forms? Carefully separate the seeds from the placenta and deposit them on a loop of

* Indicates a word that may be found in the GLOSSARY OF TERMS in the back of the lab sheets.

clear tape as demonstrated by your instructor. Tape the placenta to in the space provided on the previous page and label it. Next attach the loop of tape with your seed to the space provided on the previous page and label it.

4. Record the number of seed in the following categories:

TOTAL number of seed in the pod	TOTAL seeds_____
Number of seeds with dark seed coat	Dark Coats_____
Number of seeds with light seed coats	Light Coats_____
Number of shriveled seeds	No. Shrivel_____

5. After handling your seed and recording the quantitative measurements required above, place a second piece of clear tape over the top of seed tape to prevent you from losing seed when you turn in this lab. Make sure the cover tape holds the seed tape flat to the page.
6. Hand in the RCBr POD LABORATORY WORKSHEET after you have recorded your observations below and on your "OBSERVING THE RCBr LIFE CYCLE" master notes.

LABORATORY OBSERVATIONS

1. Do all the seeds in your pod look "exactly" the same? Why?

_____

_____

2. Why were the seeds attached to the placenta?

_____

_____

3. Were the seed coats developed by the pod (mother) or the seed?

_____

_____

4. What would be the equivalent of the pod in animal reproduction physiology and how are they similar?

_____

_____

_____

5. What might answer for the "shrivel" found in some seed?

_____

_____

6. What are your other observations?

_____

_____

_____

_____

* Indicates a word that may be found in the GLOSSARY OF TERMS in the back of the lab sheets.

NAME_____
DATE_____

DAY NUMBER Planned	Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT
0	___	PLANTING THE SEED, THE SEED AND THE GROWTH MEDIA	

You have released from it's pod a new life. It is complete in it's genetic similarity to it's parents. A predetermined kit of potential. Now you are going to affect that potential.

LABORATORY ACTIVITIES

1. Get the RCBr seeds you collected from the seed pod in the previous lab.
2. Get a styrofoam planting quad or four 35mm film cans (properly properly prepared as seed chambers.
3. Put water wicks sticking out the bottom of each chamber.
4. Fill each seed chamber half full with potting mix.
5. Add three osmocoat fertilizer pellets (14-14-14) to each seed chamber.
6. Fill each seed chamber with potting mix, but don't pack it.
7. Use a finger to make a 4 mm (quarter inch) depression in the soil of each seed chamber.
8. Place three seeds in each chamber and cover with enough potting mix to hide the seeds.
   Make sure you note the planting date, seed coat color and if the seed is shriveled for all the seeds in each chamber. Fact is, you probably should put all the same color seed in each chamber when possible. Mark each chamber with a seed description code to prevent confusion later in the experiment. Your probably should put your name on the chambers as well. (This information could recorded on plant marker stakes with water proof pen or pencil.)
9. Water gently with a pipette until water drips from each wick tip. THIS TYPE IRRIGATION WILL BE NECESSARY FOR THE FIRST THREE DAYS TO INSURE ADEQUATE MOISTURE DURING GERMINATION.
10. Place your plant quad or four film can chambers on the water mat of of the irrigation reservoir prepared by your instructor.
11. Make sure that reservoir stays full for the first 35 days of the plants' growth.
12. Record your observations as requested below.

LABORATORY OBSERVATIONS

1. Record your seed planting descriptions for each chamber in the space provided below. Use the same identity code you wrote on each chamber. This is a backup record for what you put on your chambers in case of accidents.

ID CODE_____ ID CODE_____

ID CODE_____ ID CODE_____

(ALSO SET UP A CLASS TEAM LAB ON VARIABLE AMOUNTS OF FERTILIZER, VARIABLE AMOUNTS OF WATER AND VARIABLE AMOUNTS OF LIGHT. A TEAM LAB ON GERMINATION MIGHT BE SET UP AT THIS TIME.)

* Indicates a word that may be found in the GLOSSARY OF TERMS in the back of the lab sheets.

3.

NAME_____
DATE_____

DAY NUMBER Planned	Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT
1 Thru 3	___	**LIFE SIGNS, WAITING AND WATCHING FOR GERMINATION** The stage is set and the conditions are met. A lot of the work done in applied biotechnology is setting up and maintaining the desired conditions then waiting. Consistency of conditions is a major factor. Timely observations and a record of those observations is equally important. Moisture control should be your activity focus. Observations should focus on Germination* activities. **LABORATORY ACTIVITIES** 1. Using a water dropper or used syringe, gently irrigate each seed chamber from the top. Make sure your irrigation doesn't wash the media cover from the seed planted in each chamber. 2. Check the water level in the irrigation reservoir. If necessary, refill it to the original water level. 3. As plants grow remember to maintain a 5 to 8 cm. spacing between the growing tip and the bulbs. Temperature should be in the 60 to 80 Degrees Fahrenheit range **LABORATORY OBSERVATIONS** 1. Is there any sign of plant life breaking through the media? 2. How many emerging plants do you observe? What is your percent germination? 3. How many cotyledons* do you observe per plant? 4. Can you identify the Hypocotyl* on each plant? 5 How many hypocotyl are there for each plant? 6. What color is each hypocotyl? 7. Can you find evidence of the seed coat? 8. How many seed coats were pushed to the surface? 9. What color are the exposed seed coats? 10. Is there any similarity between seed coat and hypocotyl color? 11. In the space provided below draw a picture of an emerging plant in your chambers. Label the cotyledons and hypocotyl.	_____ Day 1_____ Day 2_____ Day 3_____ _____ _____ _____ _____ _____ _____ _____ _____

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RCBr LABORATORY WORKSHEET

TEAM MEMBER NAMES

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_____ _____

TEAM NAME_____

DATE_____

GERMINATION TEACHER'S GUIDE

Subject Areas

Germination and seedling development.

Course Goals

AB8 The student will conduct germination tests

Objectives

To Observe and measure germinating seeds.

Time required

Student Observation occurs over 4 days.

Materials

For the entire class:

hand lens or stereomicroscope (optional)

fluorescent light bank

For each student:

10 RCBr seeds

hand lens or stereomicroscope (optional)

plastic grid made from photocopy of graph paper on transparency film

forceps

plastic grid

water reservoir made from plastic soda bottle

graph paper

Background

The plant embryo develops a fertilized egg in the ovary of the flower. A mature brassica seed consists of an embryo and a very small residue of endosperm* surrounded by a seed coat. The embryo is composed of cotyledons (seed leaves), root and shoot apical meristems*, the hypocotyl-root axis*, and epicotyl (the portion of the embryo axis above the cotyledons). In the brassica embryo, the epicotyl consists of little more than the apical meristem.

The seed remains dormant until internal and external conditions are appropriate for germination. Environmental factors, such as temperature and availability of water and oxygen, play critical roles in determining when germination occurs. Let nature provide the correct environmental conditions to facilitate germination and then just as quickly deprive the developing embryo for even a brief period is the subject of many nightmares every spring for agriculturalists world wide.

Most mature seeds are extremely dry, with only 5% to 20% of their total weight as water. Thus, germination is not possible until water is absorbed by the seed, a process call imbibition. Water entering the embryo hydrates proteins and other substances and triggers enzyme formation (or activation), leading to increased metabolic activity. Oxygen is required to carry out aerobic respiration. If the soil surrounding the seed is waterlogged, the amount of oxygen available may be inadequate for germination. Germination is also dependent upon temperature as it affects rates of enzyme-mediated metabolic reactions. Minimum and maximum temperatures for most species are 0 to 5 C and 45 C, with an optimum of 25 to 30 C. At either extreme, germination percentages are likely to be very low. Even with an ideal environment, some seeds will not germinate because of chemically regulated dormancy. Dormant seeds may require additional stimulators, such as light, or the breakdown of internal germination inhibitors.

When germination occurs, the first structure to emerge from the seed coat is the radicle. This helps the young seedling to absorb water and remain anchored in the soil. After the primary root emerges, the hypocotyl

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elongates, bending so the hypocotyl, rather than the shoot tip, is pushed through the soil, thus protecting the tip from injury. When the bend of the hypocotyl reaches the soul surface, it straightens, pulling the cotyledons above the soil. Under the influence of light, the cotyledons unfold, expand, and turn green. Emergence and growth of the true leaves follows. Secondary (lateral) roots develop from the first (primery) root.

The period from germination to seedling establishment is a crucial phase in the plant's life. The plant is very susceptible to injury by a wide range of insects and pathogens; water stress can prove fatal. This is a particularly dangerous period in a commercial plants' life. A farmer may invest in extra irrigation crew time or even solid sets of irrigation equipment to help guarantee the correct micro-environmental moisture levels. A nurseryman might have entire greenhouses, special pots, soil mixes and nutrient mixes set up to provide only the best conditions for seed germination. A change in this environment by an unanticipated whim of nature can result in complete or partial crop failure ruining an entire year's business plan.

Additional Exercises

1. Continue to observe the seedling and record germination percentage and average root and hypocotyl length over the course of the week. Plot these averages versus time (in days).

2. The effect of light on germination and seedling development.

a. Prepare petri dishes as described in the germination experiment. Completely cover half of them with aluminum foil so they receive no light.

b. Compare rate of germination, color and size of seedlings for the two treatment.

3. The effect of temperature of germination experiment and incubate at room temperature, refrigerator temperature, freezer temperature, and warmer than room temperature. An incubator at 30 C is ideal, but any place that is constantly warmer than room temperature will do. A small light bulb in a box makes a good incubator. Be sure to record the four different temperatures.

b. Try to make temperature the only variable. If you cannot provide equal illumination at all three temperatures, you might want to wrap the plates in aluminum foil so all seeds germinate in the dark.

c. Compare rate and percentage of germination and average root and hypocotyl length among the different treatments. Explain your results. Has the low temperature of the refrigerator killed the seeds or merely inhibited germination? To find out, have students move some of the plates to room temperature after initial measurements are completed. What criteria would you use to determine the optimum temperature for seed germination?

Glossary

apical meristem* The area of undifferentiated plant tissue at the tip of the root of shoot form which new cells arise.

dormancy* A condition of arrested growth in which the plant (or its parts) does not begin to grow without special environmental cues.

endosperm* Polypoid tissue containing stored food; formed by the union of the two polar nuclei and one male nucleus; stored food is digested by the growing sporophyte.

germination* The beginning of growth by a seed.

hypocotyl-root axis* The embryo axis below the cotyledon(s) consisting of the hypocotyl and the apical meristem of the radicle.

radicle* Embryonic root.

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RCBr LABORATORY WORKSHEET

TEAM MEMBER NAMES

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_____ _____

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TEAM NAME_____

DATE_____

GERMINATION STUDENTS' WORKSHEET

Teacher's Version

DAY NUMBER Planned Actual | ACTIVITY AND OBSERVATION | RECORD/MEASUREMENT

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0 ___ A mature brassica seed consists of an embryo surrounded by a seed coat. The embryo consists of cotyledons (the seed leaves), root and shoot apical meristems*, and the hypocotyl-root axis*. The seed remains dormant* until conditions are appropriate for germination*. Environmental factors, such as temperature and availability of water and oxygen, all play a critical role in determining when germination occurs. The first structure to emerge from the seed coat is the radicle*.

OBJECTIVES

You will observe processes associated with seed germination.

MATERIALS

10 RCBr seeds
1 small zip lock bag
1 white paper towel
hand lens or stereomicroscope (optional)
plastic grid made from photocopy of graph paper on transparency film
water reservoir made from plastic soda bottle
graph paper
plant marker stake

LABORATORY ACTIVITY

0 ___ 1. Place the plastic grid in the top of a ZIP LOCK bag with the bottom cut out. A small amount of water between the bag film and the grid will help hold the grid flat). Smooth out any wrinkles or air pockets.

2. Label the plant marker stake (use a pencil, ink will wash out) with seed type, date and time of sowing, and initials or name (Figure 1).

3. Place the cut to fit paper towel over the grid in the zip lock bag. make sure the paper towel is cut so 1 to 1.5 inches of towel extends below the cut bottom end of the bag. Wet the paper thoroughly.

4. With forceps or fingers, place 10 seeds in a row on the top line of the plastic grid (Fig.1)

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TEAM NAME_____
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DAY NUMBER Planned Actual | ACTIVITY AND OBSERVATION | RECORD/MEASUREMENT

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5. Place the zip lock/paper towel germ chamber with seeds at the top and the bottom and extended towel in the water reservoir (Figure 2).
6. Add water to a depth of 2 cm (1 inch) in the reservoir.
7. Place under fluorescent lights.

1 ___ LABORATORY OBSERVATIONS

Observe germination. Record data in Table 1. Look for any changes in seed size; the seed coat being shed; or emergence or primary root, root hairs, cotyledons, and young shoots. Examine with a hand lens to stereomicroscope. Measure the length of root and record in Table 2.

(Table 1) Number of seeds placed on the paper_____

	No.seed coats split	No.of radicles emerged	Changes in hypocotyl	Changes in root
0 ___				
1 ___				
2 ___				
3 ___				

(Table 2) Root length in millimeters

SEED NUMBER

	1	2	3	4	5	6	7	8	9	10
0 ___										
1 ___										
2 ___										
3 ___										

2 ___ 1. Observe the seedlings. What has happened to the hypocotyl? Record your observations in Table
2. What has happened to the root? Record your observations in Table 1.
3. Measure and record the root length in Table 2.

3 ___ Repeat the activities for Day 3. Draw one seedling in detail in the space provided. Label the hypocotyl, cotyledons, roots, root hairs and young shoots

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NAME_____
DATE_____

DAY NUMBER Planned	Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT
5 and 6	___ & ___	PLANT THINNING, SPACE TO GROW	

Both plants and animals have a minimal space requirement as they start life. As they mature, adequate space requirements must be met for the plants to develop in the desired fashion. The volume of media (soil) space available determines the immediately available water and nutrient supply for the plant. We plant more than one seed per chamber to insure an adequate number of plants (stand) for our purposes. Thinning guarantees that the surviving plants have an adequate supply of requirements.

LABORATORY ACTIVITIES

1. Thin to one plant per chamber using forceps. Pull plants gently from the media.
2. Transplant the extra seedlings to cells that didn't have any plants start growing in them.
3. If you have more transplants than empty chambers, prepare some extra chambers from film cans and establish the extra plants in those.
4. Mark those chambers that you transplant seedlings into for future reference. Use a plant marker stake to record the information.
5. Using a water dropper or used syringe, gently irrigate each transplant from the top. Do this daily for two days.
6. As plants grow remember to maintain a 5 to 8 cm. spacing between the growing tip and the bulbs.

LABORATORY OBSERVATIONS

1. How many chambers had more than one plant germinate in them _____
2. How many chambers had no plant germinate in them? _____
3. Of those chambers with no plants in them, how many of those ungerminated seeds were identified shriveled seeds at the beginning of the experiment? _____
4. How did the transplanted plants look within the first half hour of transplanting? _____
5. How did the seedlings left in their original chambers look within the first half hour of transplanting? _____
6. How did the transplanted seedlings look the next day? _____
7. Which plants were larger the next day, transplants or those left in their original chambers? _____
8. What observations might you make about growth rates for direct seeding (left in original chambers) versus transplanted seedlings? _____

* Indicates a word that may be found in the GLOSSARY OF TERMS in the back of the lab sheets.

TEAM MEMBER NAMES

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TEAM NAME_____
DATE_____

PHOTOSYNTHESIS TEACHER'S GUIDE

Subject Areas
Photosynthesis and plant respiration.

Course Goals
AB3 The student will describe how plants manufacture and utilize foods through photosynthesis and respiration

Objectives
To Observe physical evidence of photosynthesis and respiration

Time required
Student Observation in one class period

Materials
For the entire class:
Fast Plant cotyledons five to six days old
fluorescent light bank
0.02 M $NaHCO_3$ solution

For each student:
Small plastic soda straw
1 dark 35mm film can
1 small (5cc) disposable clear plastic syringe
A watch with minute and second recording capacity

Background

There is a contribution made by plants to our lifestyle that seldom gets the credit it deserves. The color and fragrance added to our environment is obvious. To the more informed, it is obvious that vege's and cereal products aren't run off industrial assembly lines. Closer examination will expose a tight relationship between plants and the animals we find edibly attractive. All these interactions are secondary to the most critical chemical reactions on the planet, Photosynthesis and respiration. Animals (us included) on this planet combine carbohydrates from plant and animal sources with atmospheric Oxygen and get energy to live, Carbon dioxide and water out of the reaction. The problem with this is there is only a certain amount of oxygen in the atmosphere. Use it and you lose it. Here is where plants really get into our act. They take the Carbon dioxide we exhaust combine it with water and sunlight and give off Oxygen and carbohydrates. So the life (survival) circle is complete, assuming we support plant life. Every carbon atom in an animal's body, every molecule of oxygen breathed once cycled through plants, algae or some photosynthetic organism. Photosynthetic and nonphotosynthetic life forms "burn" these organic compounds through glycolysis, fermentation, and respiration which all consume Oxygen and release Carbon dioxide back into the atmosphere.

This reaction, photosynthesis, is the only practical method of harvesting the suns energy. It turns light energy striking the plant surface into chemical energy called ATP and ADP. For all our mental superiority, we cannot duplicate the efficiency of solar energy conversion that plants do simply conducting their lower life cycle. Poses an interesting question about species superiority doesn't it. Without the building and breaking down carbohydrate molecules the energy of the sun would not be available in any usable form and most life on Earth would terminate rather abruptly.

This laboratory exercise will allow you to explore the rates of photosynthesis and respiration in Fast Plants. The rate at which Oxygen is produced will be used to measure the rate of photosynthesis and the rate of Oxygen consumption will be used as a measure of the respiration rate.

* Indicates a word that may be found in the GLOSSARY OF TERMS in the back of the lab sheets.

TEAM MEMBER NAMES

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Glossary

Photosynthesis The conversion of light energy to chemical energy; the manufacture of carbohydrates (sugars) and oxygen by plants in the presence of light and chlorophyll

Respiration The process by which an organism or cell takes in oxygen distributes and utilizes it in oxidation and gives off carbon dioxide water and energy.

cotyledon A primary embryonic leaf.

CHEMICAL EQUATIONS

PHOTOSYNTHESIS

$$6CO_2 + 6H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2$$

RESPIRATION

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 686 \text{ kcal energy}$$

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RCBr LABORATORY WORKSHEET

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PHOTOSYNTHESIS STUDENTS' WORKSHEET
Teacher's Version

DAY NUMBER Planned Actual | ACTIVITY AND OBSERVATION | RECORD/MEASUREMENT

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0 ___ There is a contribution made by plants to our lifestyle that seldom gets the credit it deserves. The color and fragrance added to our environment is obvious. To the more informed, it is obvious that vege's and cereal products aren't run off industrial assembly lines. Closer examination will expose a tight relationship between plants and the animals we find edibly attractive. All these interactions are secondary to the most critical chemical reactions on the planet, Photosynthesis and respiration. Animals (us included) on this planet combine carbohydrates from plant and animal sources with atmospheric Oxygen and get energy to live, Carbon dioxide and water out of the reaction. The problem with this is there is only a certain amount of oxygen in the atmosphere. Use it and you lose it. Here is where plants really get into our act. They take the Carbon dioxide we exhaust combine it with water and sunlight and give off Oxygen and carbohydrates. This laboratory is designed to demonstrate photosynthetic and respiratory activity in plant tissue. It will also provide an opportunity to compare the relationship between photosynthetic activity and the amount available light.

OBJECTIVES

To Observe physical evidence of photosynthesis and respiration

MATERIALS

Small plastic soda straw
1 dark 35mm film can
1 small (5cc) disposable clear plastic syringe
Fast Plant cotyledons five to six days old
fluorescent light bank
0.02 M $NaHCO_3$ solution, prepared by instructor in advance
A watch with minute and second reading capacity.

LABORATORY ACTIVITY

5 ___ 1. Remove the plunger from the syringe.
2. Place a finger over the needle end of the syringe and fill the syringe half
more full.
3. Have a lab partner punch four leaf discs from the cotyledons of the provided Fast Plants using the plastic soda straw.
4. With the four leaf disks in the end of the soda straw, carefully blow the disks into the solution in the syringe.
5. Replace the plunger in the syringe and point the syringe needle end up and expel any air in the barrel of the syringe, carefully.
6. The leaf disks should float in the top of the syringe barrel due to intercellular air and gasses.
7. Remove the air in the leaf by placing a finger tightly on the needle end opening of the syringe and pull on the plunger. The vacuum created will cause the leaf disks to become saturated with liquid and sink. If they don't, repeat step 7.
8. Place the syringe in an upright position within 10cm of the plant lights. Note the starting time in minutes and seconds.
9. Observe the time required for each disk to float. Record the elapsed times in the provided data table.

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RCBr LABORATORY WORKSHEET

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5 ___ 10. Once all disks are floating, cover the syringe with the dark film can. Record the starting time.

11. Record the time required for each disk to sink. Record the results in provided data table.

12. When all disks have sunk, clean up the syringe and any mess you made.

5 ___ LABORATORY OBSERVATIONS

1. Record your laboratory observations in the table provided below.

PHOTOSYNTHETIC ACTIVITY DATA TABLE

Experiment starting time_____(min/sec)

Time Min/Sec	No.of disks floating	Total Sec.	Time Min/Sec	No.of disks Sunk	Total Sec.
	1			1	
	2			2	
	3			3	
	4			4	

Time for 50% of submerged disks in light to float (secs.) _____ T50% float

Time for 50% of floating disks in dark to sink (secs.) _____ T50% sink

2. The rate of respiration in the leaf disks can be computed as proportional to the inverse of the T50% sink time. Using the formula provided below calculate the rate of respiration for these Fast Plant tissue samples.

Rate of Respiration = 1/T50% sink = _____

3. Both photosynthesis and respiration take place during daylight periods. This complicates the calculation of photosynthetic rate problem slightly but not completely. We will borrow your answer for Rate of Respiration, problem 2 answer, and plug it into the formula for Rate of Photosynthesis. Using the formula provided below, calculate the Rate of Photosynthesis.

Rate of Photosynthesis = 1/T50% float + 1/T50% sink = _____

4. Calculate the ratio of RATE OF PHOTOSYNTHESIS : RATE OF RESPIRATION

RATE OF PHOTOSYNTHESIS/RATE OF RESPIRATION : 1

RATE OF PHOTOSYNTHESIS:RATE OF RESPIRATION = _____: 1

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RCBr LABORATORY WORKSHEET

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4. Write the chemical equations for both photosynthesis and respiration in the designated spaces below.

PHOTOSYNTHESIS CHEMICAL EQUATION

Light

_____ + _____ ----------> _____ + _____

RESPIRATION CHEMICAL EQUATION

_____ + _____ ----------> _____ + _____ + _____

5. Why did the submerged disks in the light gradually float?

6. Why did the floating disks in the dark gradually sink?

7. What does the rate of Photosynthesis : rate of Respiration ratio tell you about the energy balance of your fast plants?

8. How might other plants store excess energy generated by this beneficial energy balance?

List four examples that benefit man please.

1._____
2._____
3._____
4._____

OTHER EXPERIMENTS THAT DESERVE CONSIDERATION

Would different wave lengths of light provide different results.
How would the photosynthetic rate of regular Fast Plants compare to the mutant yellow green Fast Plants (deficient in chloroplasts)?
How would photosynthetic rates compare between cotyledon leaf disks and mature Fast Plant leaf disks?
How do Fast Plants compare with other plants?
What would happen if you compared rates between properly lit Fast Plants and some that have been deprived of light?

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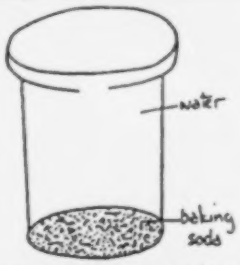
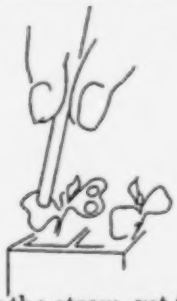
9C

PHOTOSYNTHESIS/RESPIRATION

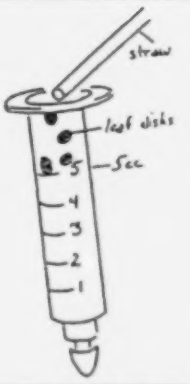


1. Add enough baking soda to cover the bottom of a film can. Fill can with water, add lid and shake to dissolve baking soda.



2. Using the straw, cut four leaf discs from cotyledons of five or six day-old Fast Plants.

3. Remove cap from the tip of syringe. Pull the plunger out of the syringe. Blow the leaf discs out of the straw into the syringe. Replace the plunger.

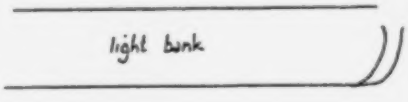


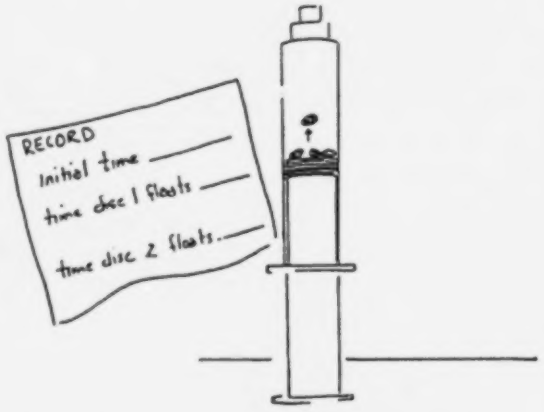
4. Draw 4cc of baking soda solution into the syringe. Invert syringe as shown, tip-end up. Gently push the plunger to remove all the air.

5. Put your finger over the syringe tip and pull plunger firmly. . This will create a vacuum which will pull the air and oxygen from the leaf discs.

6. Tip the end of syringe down so that leaf discs are in the solution. Release plunger; remove your finger. Turn syringe back up and tap the side repeatedly until all (or most) of the discs sink.

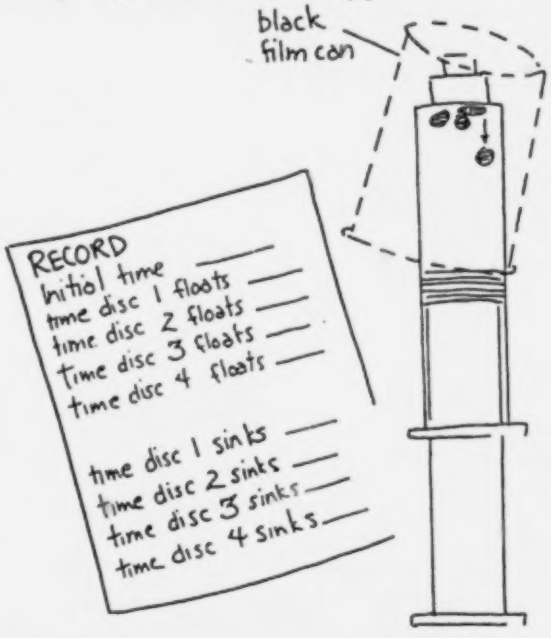
7. Place the syringe narrow-end up about 5 cm from the light bank lights, or in bright sunlight. Record the time.





8. As leaf discs photosynthesize and produce oxygen, they will float to the top. Record the time at which each disc floats.

9. After all discs refloat, cover the top of syringe. The leaf discs will sink again as they respire and consume oxygen.



10. Record the time at which each disc sinks.

RCBr PCO LABORATORY WORKSHEET

NAME_____
DATE_____
SEED ID_____

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MIXING MOLAR CONCENTRATE SOLUTIONS

There is a time in every young plant breeder's experience when they must consummate the marriage of their science and math skills. This lab addresses that need. To complete your studies of FAST PLANTS it will be necessary to mix chemical solutions to very specific concentrations. If the concentrations are measured in Moles*, you will need to know how much concentrate to mix with how much fluid to achieve the desired molarity. A mole is the number of grams weight of a chemical compound required to equal the atomic weight of that compound. Knowing how many grams of the compound necessary to achieve the desired molarity of solution is what this entire lab is directed towards. The solution used for problem examples in this lab is the one required for the Photosynthesis lab of this unit. Your will be using molar solutions in other unit labs so master this measurement skill.

OBJECTIVES
To measure and mix a prescribed molarity solution.

MATERIALS
NaHCO3 (Sodium Bicarbonate)
Weighing paper
Balance scales (Metric)
Graduated cylinder (measuring liter flask)
Water
Periodic Table of Elements

LABORATORY ACTIVITY

1. Using the provided periodic table, look up the atomic weight of each chemical element in Sodium Bicarbonate (NaHCO3). Write that atomic weight down in the spaces provided below

ELEMENT	ATOMIC WEIGHT
Na	_____
H	_____
C	_____
O	_____

2. Multiply the atomic weights of each element times the number of atoms of each element found in the formula of the solute compound NaHCO3 (Sodium bicarbonate). Right the answers in the space found below. Total element molar weights, record your answer in the space provided.

ELEMENT	ATOMIC WEIGHT		NO.OF ATOMS USED		MOLAR WEIGHT IN GRAMS
Na	_____	X	_____	=	_____
H	_____	X	_____	=	_____
C	_____	X	_____	=	_____
O	_____	X	_____	=	_____
					_____ MASS MOLAR WEIGHT

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3. This experiment requires that you mix a .02 Molar solution of Sodium Bicarbonate. (.02 M $NaHCO_3$).
4. Determine the volume of solution, in milliliters (ml), you wish to mix and plug that figure as well as your compound molar weight into the formula provided below. Record your answers in the space provided.

Amount of Solution desired?_____ml
Molarity of solution desired?_____Molar

$$\text{Grams of Solute} = \frac{\text{VOLUME OF SOLUTION IN MILLITERS} \times \text{MOLARITY} \times \text{MASS OF 1 MOLE OF SOLUTE}}{1000}$$

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NUTRIENTS AND THE SEED MICRO-ENVIRONMENT

TEAM MEMBERS

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TEAM NAME_____

LAB START DATE_____

SEED ID_____

There are a number of environmental factors (variables) that can affect the seed's completion of it's life cycle. This experiment is designed to look at the effect varying only the plant nutrition factor. All other factors affecting seed growth will be kept as uniformly similar to the conditions established in the base PLANTING THE SEED, THE SEED AND THE GROWTH MEDIA lab as is possible. The seed's micro environment is created by a combination of climactic and chemical influences that you have total control over in this experiment. To insure that the changes and differences you observe in this experiment are attributed to a change in NUTRITION, do your best to keep all other factors as close as possible to those being maintained in the base experiment, PLANTING THE SEED, THE SEED AND THE GROWTH MEDIA lab. The following work sheet has been developed to help direct and organize our observations. It progresses *chronologically from planting day to harvest day. There is going to be a consistent flow of laboratory activities (things to do) and observations (things to see and record). These exercises must be accurately accounted for two basic reasons. 1) To most critically compare earlier activities and observations with current developments within this experiment and in comparison to the base experiment and 2) To accumulate all the pieces necessary for successful completion of your final report. There are going to be questions that you don't have an immediate answer for. Ask, you might get an answer. Observe, measure, compare and discriminate and you will get an answer.

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0 ___ PLANTING THE SEED, THE SEED AND THE GROWTH MEDIA

You have released from it's pod a new life. It is complete in it's genetic similarity to it's parents and those seeds established in the base experiment. Now you are going to affect that potential environmentally. The nutrition factor is our only variable and only it will be changed from chamber to seed chamber.

LABORATORY ACTIVITIES

1. Get the RCBr seeds selected for you.
2. Get 6 styrofoam planting quads or 24 35mm film cans (properly prepared as seed chambers.
3. Put water wicks sticking out the bottom of each chamber.
4. Fill each seed chamber half full with potting mix.
5. Add osmocoat fertilizer pellets (14-14-14) to each seed chamber placing 0 pellets to the first chamber and then one more pellet to the next chamber. Increase your pellet count by one until all the chambers are fertilized with nutrient levels ranging from 0 to 24 pellets varying by one pellet per chamber. PLEASE permanently mark the pellet count on each chamber (plant marker stakes). After completing the rest of the steps, put these chambers under the lights in numerical order by pellet count.
6. Fill each seed chamber with potting mix, but don't pack it.
7. Use a finger to make a 4 mm (quarter inch) depression in the soil of each seed chamber.
8. Place three seeds in each chamber and cover with enough potting mix to hide the seeds.

Make sure you note the planting date, and select as uniform a set of seed as possible for each chamber. Fact is, you probably should put all the same color seed in each chamber when possible. Mark each chamber with a seed description code to prevent confusion later in the experiment.

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You should put your name on the chambers as well. (This information could recorded on plant marker stakes with water proof pen/pencil.)

9. Water gently with a pipette until water drips from each wick tip. THIS TYPE IRRIGATION WILL BE NECESSARY FOR THE FIRST THREE DAYS TO INSURE ADEQUATE MOISTURE DURING GERMINATION.
10. Place your plant quads or 24 film can chambers in numerical order by osmocoat pellet count on the water mat of the irrigation reservoir prepared by your instructor.
11. Make sure that reservoir stays full for the first 35 days of the plants' growth.
12. Record your observations as requested below.
13. Use the fertilizer pellet count marked on each chamber to identify the plants for results recording.

LABORATORY OBSERVATIONS

The following questions deserve consideration as you conduct your observations. You will be expected to be able to respond to these in your LABORATORY RESULTS REPORT due at the end of these experiments.

1. All things equal, does available plant nutrition affect plant growth? In general terms, How?

2. Is there such a thing as too much fertilizer? How can you tell?

3. What aspects of plant life seems to be affected by too much or too little fertilizer?

4. What are the commercial implications to this too much too little fertilizer?

5. What are the production considerations of too much or too little fertilizer?

6. How many grams of fertilizer did you put in the chamber? How many grams weight did the plant gain? How Come?

7. What factors are affected by plant height?

8. What factors are affected by plant flowering time?

9. What factors are affected by number and size of seed pods?

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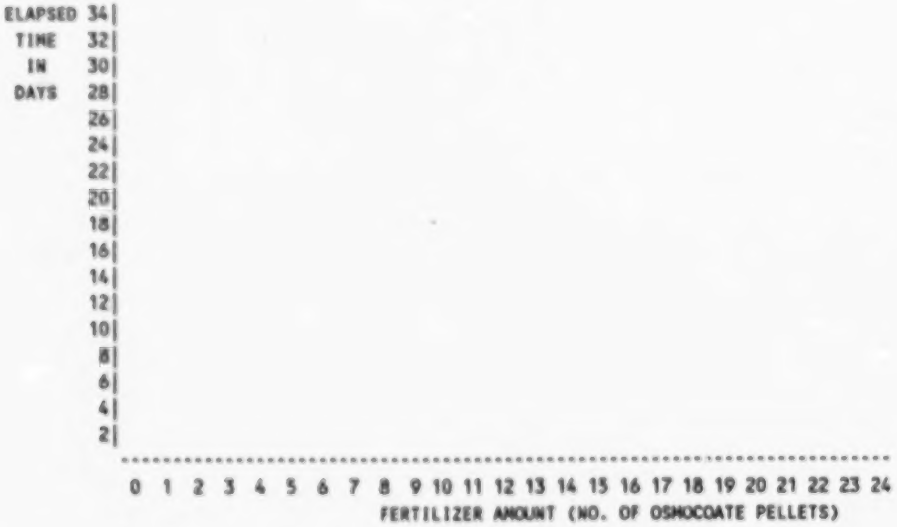
DAY NUMBER Planned Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT

1. FERTILIZER (PLANT NUTRIENTS) AND GROWTH TIME
   What effect does the level of fertilizer have on elapsed time from planting to plant maturity?
   Using the legend provided below, graph the days of elapsed time it to reach each growth stage event for each plant.

   Place an "E" on the graph to identify the number of days to plant soil EMERGENCE for each plant.
   Place a "T" on the graph to identify the number of days to plant first TRUE leaf emergence for each plant.
   Place a "F" on the graph to identify the number of days to plant first FLOWER opening for each plant.
   Place a "M" on the graph to identify the number of days to plant first MATURE full pod development for each plant.
   Place a "D" on the graph to identify the number of days to plant confirmed signs of plant DEATH for each plant. Death is part of carbon based life forms.



1 _____ Check for beginning emergence.

5 _____ Check for first true leaf buds.

12 _____ Check for first open flower.

25 _____ Check for first full pods.

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DAY NUMBER Planned	Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT

2. FERTILIZER (PLANT NUTRIENTS) AND PLANT HEIGHT

What effect does the level of fertilizer have on plant height and how fast a plant grows up?

Using the legend provided below, graph the days of elapsed time it to reach each growth stage event for each plant.

Place an "5" on the graph to identify the height of the plant at at day FIVE of plant development for each plant.

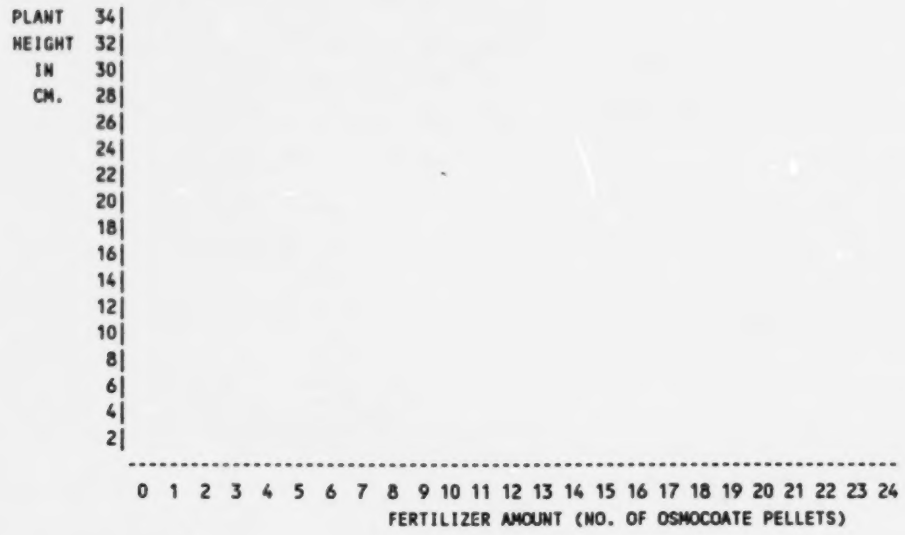
Place a "T" on the graph to identify the height of the plant at first TRUE leaf emergence for each plant.

Place a "F" on the graph to identify the height of the plant at first FLOWER opening for each plant.

Place a "M" on the graph to identify the total MATURE plant height at day 15.

Place a "P" on the graph to identify the height of the tallest seed pod on each plant at day 25.

Place a "D" on the graph to identify the height of the plant at confirmed signs of plant DEATH for each plant. Death is part of carbon based life forms.



5 ____ Check height of plants.

5 ____ Check height of first true leaf bud.

15 ____ Check height of first open flower.

15 ____ Check total height of plant.

25 ____ Check height of tallest seed pod.

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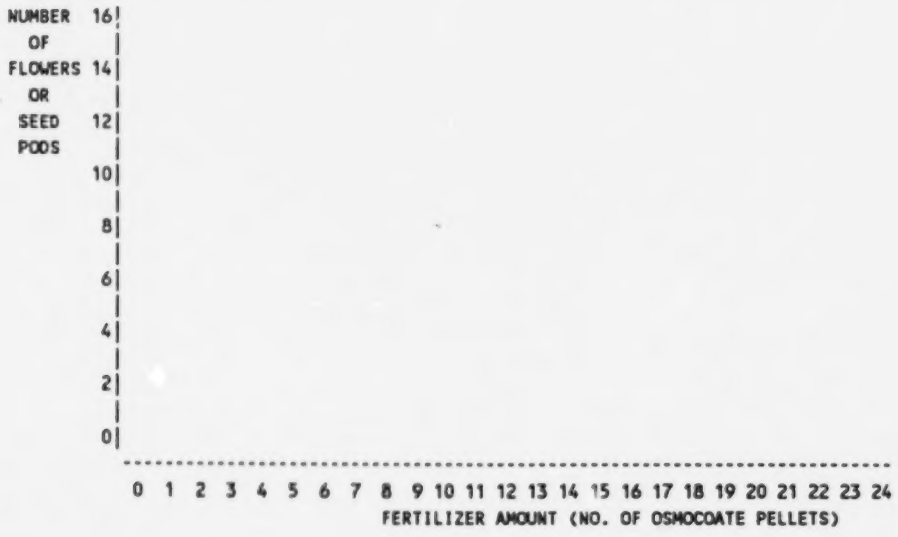
3. FERTILIZER (PLANT NUTRIENTS) AND NUMBERS OF PLANT ORGANS
What effect does the level of fertilizer have on plant reproduction capacity. Reproduction in plants is a function of the number and fertility of flowers and the availability of pollen. Using the legend provided below, graph the number of flowers available the first three days of flower set and the number of seed bearing pods that develop from those flowers. Remember to pinch off all flowers opening after three days to continue to encourage rapid cycling life times. Keep an accurate record of the total number of flowers each plant sets, even if you do pinch off those opening after the first three days.

Place a "F" on the graph to identify the number of FLOWERS opening and pollinated during the first three days of flower opening for each plant.
Place a "T" on the graph to identify the TOTAL number of flowers set by each plant even if you did pinch them off after three days.
Place a "P" on the graph to identify the total number of seed bearing PODS that develop from the pollinated flowers.
Place a "D" on the graph to indicate those plants that DIED before pollination or seed pod set for each plant. Death is part of carbon based life forms.



12 ____ Start checking for open flowers and pollinating

15 ____ Start pinching unfertilized flowers.

25 ____ Start checking for seed bearing pods.

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4. FERTILIZER (PLANT NUTRIENTS) AND PLANT WEIGHTS

What effect does the level of fertilizer have on total plant growth. Plants grow in height, number and size of leaves, volume of roots, stem size, number and size of seed pods and other areas. Measuring all those organs could be a book keeping nightmare. What we will do instead is measure total plant weight. Weigh each plant quad or film can plant chamber individually. If your are growing in quads, weigh a quad and divide the answer by four. Record the average answer for for each plant in the weighed quad. Make sure the plant chambers are uniformly wet from the water wick pad every time you weigh them. Take your first weight at day 5 of the experiment..

Place a "1" on the graph to identify the weight of the plants at day 5.

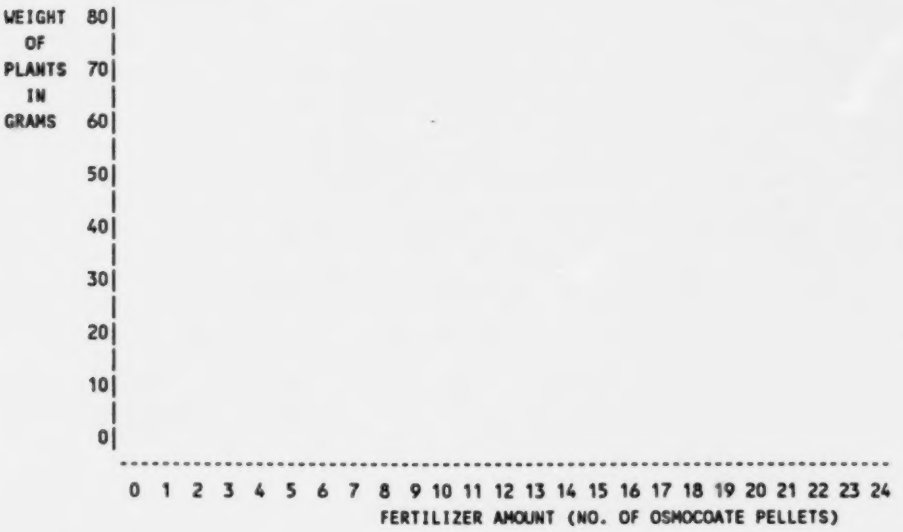
Place a "2" on the graph to identify the weight of the plants at day 10.

Place a "3" on the graph to identify the weight of the plants at day 15.

Place a "4" on the graph to identify the weight of the plants at day 20.

Place a "5" on the graph to identify the weight of the plants at day 25.

Place a "D" on the graph to indicate those plants that DIED at any at any point in this portion of the experiment. Death is a part of carbon based life forms.



5 ____ First weighing of plants.
10 ____ Second weighing of plants.
15 ____ Third weighing of plants.
20 ____ Fourth weighing of plants.
25 ____ Fifth weighing of plants.

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7 ___ VEGETATIVE DEVELOPMENT, COUNTING THE LEAVES

Plants get virtually all their energy from the sun. Their solar collectors are the leaves. Photosynthesis is the process. It takes leaf surface area to act as the collecting surface and as the processing factories that convert solar energy into chemical energy.

LABORATORY ACTIVITIES

1. Count the number of leaves including cotyledons. _____leaves

ID CODE_____	ID CODE_____
No. of leaves_____	No. of leaves_____
No. of leaves_____	No.of leaves_____

ID CODE_____ ID CODE_____

2. Diagram the placement of those leaves on the main stem. Make your drawings from both the side and top views.

LABORATORY OBSERVATIONS

1. Why are the leaves arranged as they are on the stem?

2. What might a plant breeder do to increase the photosynthetic efficiency of a plant?

2. Write the chemical equation for photosynthesis? Under each chemical component write the source of chemical input or examples of the product we use from plants.

ARRANGE CLASS TEAM LABS TO DEMONSTRATE PHOTOSYNTHESIS AND RESPIRATION IN PLANT PROCESSES.

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10 ___	VEGETATIVE DEVELOPMENT, LENGTH OF 2ND. TRUE LEAF	

Plants get virtually all their energy from the sun. Their solar collectors are the leaves. It takes leaf surface area which accomplished by both number of leaves and leaf size. We are going to measure the second true leaf of your plants as our reference leaf. It should be one of the largest leaves on your plant.

LABORATORY ACTIVITIES

1. Measure the length of the 2ND. TRUE LEAF from node to apex. Record your answers for each plant in your quad. Measure in cm.

ID CODE_____	ID CODE_____
No. of leaves_____ lngth.2nd.true leaf_____	No. of leaves_____ lngth.2nd.true leaf_____
No. of leaves_____ lngth.2nd.true leaf_____	No.of leaves_____ lngth.2nd.true leaf_____
ID CODE_____	ID CODE_____

LABORATORY OBSERVATIONS

1. What was the longest 2ND. TRUE LEAF measured? _____cm length
2. What was the leaf count of the plant with the largest 2ND. TRUE LEAF? _____leaf count
3. What was the shortest 2ND. TRUE LEAF measured? _____cm length
4. What was the leaf count of the plant with the smallest 2ND. TRUE LEAF? _____leaf count
5. Is there any apparent relationship between leaf count and leaf size? _____
6. How would you determine if leaf size is heritable?

7. What other factors might influence leaf size?

8. Is there a negative side to increased leaf size? List some examples.

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NAME_____
DATE_____

DAY NUMBER Planned Actual | ACTIVITY AND OBSERVATION | RECORD/MEASUREMENT

12 ___ VEGETATIVE DEVELOPMENT, PLANT HEIGHT

Plants get virtually all their energy from the sun. Their solar collectors are the leaves. As leaf surface is being established, is needs to be provided a mechanism to help insure that surface space will be exposed to the sun. Vertical growth helps provide that opportunity. This lab examines and compares the mechanisms of plant height.

LABORATORY ACTIVITIES

1. Measure the height of each of your plants from the cotyledon node to the shoot apex. Measure in cm. and record your answers below.

ID CODE_____	ID CODE_____
No. of leaves_____ lngth.2nd.true leaf_____ plant height_____	No. of leaves_____ lngth.2nd.true leaf_____ plant height_____
No. of leaves_____ lngth.2nd.true leaf_____ plant height_____	No.of leaves_____ lngth.2nd.true leaf_____ plant height_____
ID CODE_____	ID CODE_____

LABORATORY OBSERVATIONS

1. What was the longest plant measured? _____cm length
2. What was the 2ND TRUE LEAF length of the longest plant? _____leaf length
3. What was the shortest plant length recorded? _____cm length
4. What was the 2ND TRUE LEAF length of the shortest plant? _____leaf length
5. Is there any apparent relationship between plant length and leaf size? _____
6. How would you determine if plant length is heritable?

7. What other factors might influence plant length?

8. Is there a negative side to increased plant length? List some examples.

* Indicates a word that may be found in the GLOSSARY OF TERMS in the back of the lab sheets.

NAME_____
DATE_____
SEED ID_____

THE EFFECTS OF GIBBERELLIC ACID ON WILD-TYPE AND ROSETTE PLANTS STUDENTS' WORKSHEET

DAY NUMBER Planned	Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT
0	___	Normal plant development depends on the interplay of a number of internal and external factors. Principle internal factors that regulate growth and development in plants are the hormones. Hormones are organic substances produced in one tissue and transported to another tissue, where their presence results in a physiological response. Hormones are active in a very small quantities. The rosette phenotype in RCBr is conditioned by a single gene mutation which, in the homozygous condition ros/ros, results in 4 to 10 times less gibberellin in the tissues. The internodes of rosette plants do not elongate, and the leaves lie flat against the soil (Figure 1). The flowers cluster above the leaves forming an extremely dwarf plant. Norman flower development is retarded and production of seeds is severely limited. OBJECTIVES To investigate the role of one class of hormones, the gibberellins, by treating plants with gibberellic acid (GA) and observing the results. REQUIRED EQUIPMENT AND MATERIALS For each group of students: 6 RCBr wild-type seeds 6 rosette seeds (ros/ros) quads and necessary planting materials 2 disposable pipets rulers PRE-LAB QUESTIONS 1. What plant parts in the rosette plant will show the effect(s) of added GA? 2. a. What other plant hormones will produce the opposite effect of GA? b. What other plant hormone will produce the same effect as GA? LABORATORY ACTIVITY	
0	___	1. Following the "Growing Instructions," plant each of two cells of your quad with three wild-type seeds. Label one "Wild Type, Water" and the other "Wild Type, GA." Plant each of the other two cells of the quad with three rosette seeds. Label one cell "Rosette, Water" and the other "Rosette, GA." Follow the procedures in the "Growing Instructions" to the end of the life cycle of the plants, adding the steps listed below.	
8 thru 16	___	2. Label one pipet "Water" and the other "GA." Day 8 to 16 (starting on day 8 and every other day until flowering; Figure 2)	
		1. Record plant height (distance along the stem from the point of cotyledonary attachment to the very tip of the plant). Measure in cm to the nearest mm and record in Table 1. 2. According to the treatment labels, apply one drop of GA or water to each leaf on your plants, using the proper pipet.	

* Indicates a word that may be found in the GLOSSARY OF TERMS in the back of the lab sheets.

NAME_____
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SEED ID_____

DAY NUMBER Planned Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT
20 ___	Pool the class data and calculate the class averages for each date. Using class averages, construct two growth curve graphs, one for the wild-type plants (Graph 1), and one for the rosette plants (Graph 2). Graph time on the horizontal axis and height on the vertical axis.	

Figure 2. Effect of GA on rosette plant.

TABLE 1. PLANT HEIGHT
Date of Planting_____
Height (in cm)

DAY NUMBER Planned actual	Wild-type plant				Rosette plant			
	Water-treated		GA-treated		Water-treated		GA-treated	
	Yours	Cl.Ave.	Yours	Cl.Ave	Yours	Cl.Ave.	Yours	Cl.Ave
8 ___								
9 ___								
10 ___								
11 ___								
12 ___								
13 ___								
14 ___								
15 ___								
16 ___								

* Indicates a word that may be found in the GLOSSARY OF TERMS in the back of the lab sheets.

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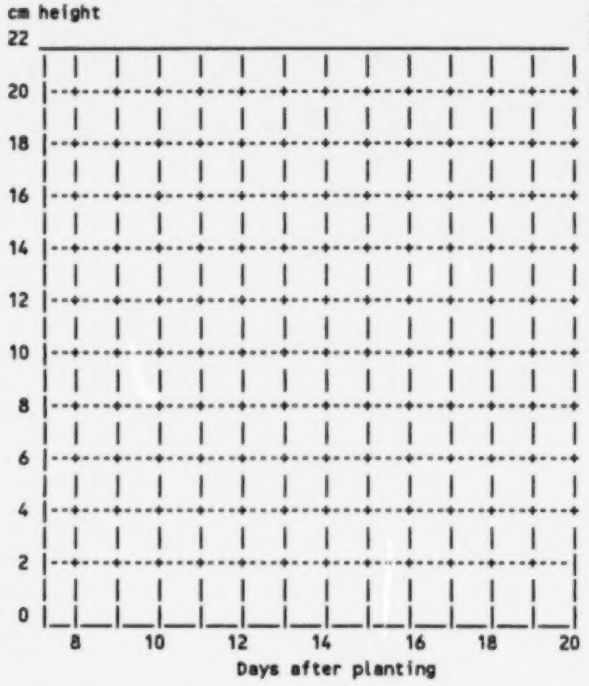
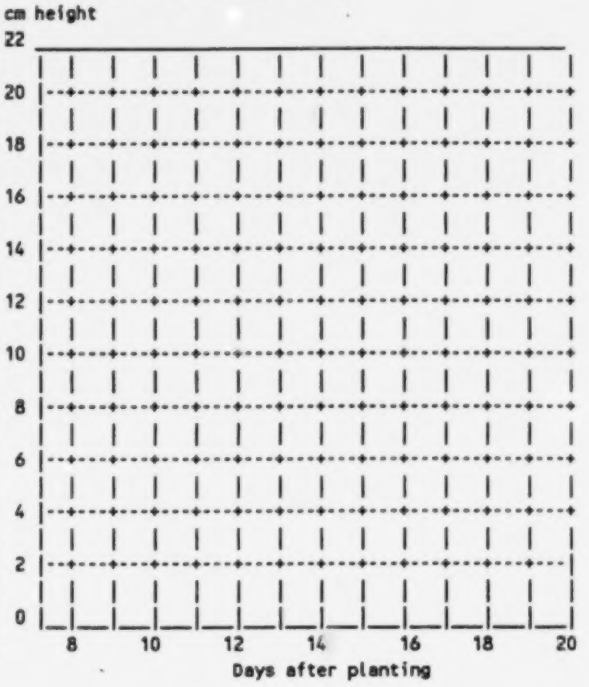
NAME_____
DATE_____
SEED ID_____

DAY NUMBER Planned Actual | ACTIVITY AND OBSERVATION | RECORD/MEASUREMENT

GRAPH 1. Wild-type Plants



GRAPH 2. Rosette Plants



1. What is the effect of GA on plant growth in the rosette mutant?

2. What is the effect of GA on plant growth in a wild-type plant?

3. How can you explain the variation in response found within the class for the treated rosette plants?

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DAY NUMBER Planned Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT

4. Make a comparison of the water-treated plants and the GA-treated plants. Do your results prove that the rosette is a gibberellic acid-deficient mutant? Explain.

5. Would varying the location of the application affect the plant growth response? Design an experiment to test your hypothesis.

6. What environmental factors can affect stem elongation?

7. What are some of the consequences of stem elongation to a commercial producer of seed?

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NAME_____
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SEED ID_____

THE EFFECTS OF GIBBERELLIC ACID ON WILD-TYPE AND ROSETTE PLANTS

TEACHER'S GUIDE

Subject Areas
Plant physiology: growth and development.

Objectives
To investigate the role of one class of hormones, the gibberellins, by treating plants with gibberellic acid (GA) and observing the results.

Time Required
Student observations occurs over 25 days.

Materials
For the entire class:
Hormone Kit
fluorescent light bank
rulers

Background

The effects of gibberellins were first investigated in connection with the "foolish seedling disease" of rice (caused by the fungus Gibberella fujikuroi). Plants infected with the fungus grew very rapidly, became much taller than normal, and fell over. It was found that extracts of the fungus mimicked the disease. The effect was due to the fungus producing an excess of chemical which is normally present in plants in minute amounts-regulating substances named gibberellins.

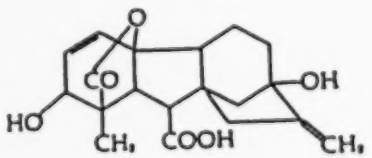
Many dwarf of bushy plants are gibberellin-deficient and will grow tall when gibberellin is supplied because of its effects on cell division and elongation. Gibberellins are also involved in flowering, seed germination, and the breaking of seed dormancy. Gibberellins interact with other hormones; many growth-regulating effects are due to the balance between levels of different hormones.

There are many gibberellins known--all with the same basic structure but differing in side chains or substitutions. Different plants have different types of gibberellins. Although the different gibberellins have similar effects, in many cases a species is sensitive only to the gibberellins it produces.

Gibberellins are synthesized in different parts of the plant, but especially in actively growing areas such as embryos and meristematic or developing tissues. They seem to move freely in the plant, and their transport and distribution is not polar, as with auxins.

Gibberellins are used commercially in agriculture for a variety of purposes. Grape flowers can be treated with GA is also used to increase petiole length (and thus yield) of celery and rhubarb, to break dormancy of seed potatoes, and to delay fruit maturity in fruit crops to extend harvest (Bidwell, 1974).

Figure 1. Structure of a gibberellin.



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Glossary

auxin A growth hormone which influences cell elongation and is involved with geotropic and phototropic responses. In unequal amounts, auxin causes a curvature of the tissue in stems and roots by causing cells to elongate differentially.

meristem The undifferentiated plant tissue from which new cells arise.

gibberellins A group of growth-regulating substances best known for increasing the elongation of stems.

hormone A chemical substance produced, usually in minute amounts, in one part of an organism and transported to another part of the same organism, where is has a specific effect.

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NAME_____
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PLANT RESPONSES TO LIGHT AND GRAVITY
TEACHER'S GUIDE

SUBJECT AREAS

Plant physiology: growth and development

OBJECTIVES

To understand plant responses to light and gravity at different ages and to distinguish between effects of light and effects of gravity.

TIME REQUIRED

Investigation I
Student observation---Occurs over 4 days.
Teacher preparation___Seedlings need to be started 3 to 5 days in advance. If they are being sown just for this exercise, sow 5 to 6 seeds per cell.

Investigation II
Student observation---About 2 hours.

Teacher preparation---Seedlings need to be started about 2 weeks ahead or use plants from Investigation I. Transplant seedlings into quads and conduct Investigation II when plants are 12 to 14 days old.

MATERIALS

Investigation I
For the entire class:
- fluorescent light bank
- plastic film sheets---red, green, blue
- hand-held paper punch or electric drill and 13/64" drill bit
- clear plastic tape and black plastic electrical tape

For each group of students:
- 4 film canisters from 35-mm film
- 4 pieces of paper towel, each 2-cm square
- 9 RCBr seeds and 2 seedlings (3 to 5 days old)

Investigation II
For the entire class:
- fluorescent light bank
- two light-excluding boxes

For each group of students:
- four quads of RCBr plants (12 to 14 days old)
- protractor

BACKGROUND

Why do roots grow downward and stems grow upward? These responses appear to be mediated by the root cap and shoot tip. In roots, perception of the direction of gravity appears to be related to the settling of organelles called amyloplasts in specialized root cap cells. When the plant is turned, amyloplasts sink toward the source of gravity and accumulate on the side of the cell that is currently "down." Curving of the roots results from asymmetric growth as the root elongates. Elongation of plant cells is affected by a plant hormone call auxin. Auxin concentration appears to parallel amyloplast distribution, leading to a gravity-induced auxin gradient across the shoot or root tip. In roots, calcium levels rise where amyloplasts accumulate. This may activate

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ion pumps in the membrane to pump calcium and auxin out of the lower side of the cells, so calcium and auxin out of the lower side of the cells, so calcium and auxin accumulate at the lower side of the root cap. Current research shows that auxins may not be the only hormone involved. Auxin stimulates cell elongation in shoots but inhibits it in roots, so the same system allows roots to bend toward the source of gravity (positive gravitropism) and shoots to bend away from it (negative gravitropism). Negative gravitropism causes plant shoots to grow upward. An important control is lacking from experiments done so far---growing plants in zero gravity.

The plant's response to light (phototropism) is mediated by the shoot tip and has been studied most in coleoptiles (the sheath around cereal grain shoots). Unequal auxin distribution also appears to be involved, with auxin apparently transported away from the lighted side toward the darker side of the shoot. Since auxin stimulates cell elongation in shoots, this causes a greater degree of cell elongation on one side of the shoot, and the shoot bends toward the light. Research has show phototropism to be response to blue light, but the nature of the receptor and the response is not well understood.

Phototropic and gravitropic responses share several properties. A physical stimulus (gravity or light) leads to unequal distribution of auxin. The change in auxin distribution is thought to result form lateral migration of auxin rather than from differential synthesis or degradation. Root or shoot bending is due to differential cell elongation is response to differing auxin concentrations.

ADDITIONAL EXERCISES

1. For Investigation I:
   a. Subject plants to different photoperiods.
   b. Use different filter colors over windows (three per chamber) to test direction of growth.
   c. Use different growth orientations to study tropism.
   d. Using differently sized windows covered with clear plastic, demonstrate the effects of light intensity, angle of incidence, etiolation.
   e. A set of chambers, each with different colored windows, can be used to show the effect of light color on germination and early growth stages.
   f. Black electrical tape applied over the clear tape can exclude light from the chamber for a portion of the experiment.
   g. Place a chamber on its side with the window down (turn it enough so some light can get in). Will the response be stronger to light or to gravity?

2. For Investigation II:
   a. Allow the plant to grow a day or two and then turn it again.
   b. Use quads of plants of different ages, from seedlings to mature plants (with pods, but not dried), to ascertain more about the response of tissues of different ages.

GLOSSARY

amyloplasts A colorless plastid that stores starch.

auxin A growth hormone which influences cell elongation and is involved with geotropic and phototropic responses. In unequal amounts, auxin causes a curvature of the tissue in stems and roots by causing cells to elongate differentially.

gravitropism The response of a shoot or root to the pull of the earth's gravity.

phototropism Growth in which the direction of light is the determining factor; turning or bending in response to light.

root cap A thimble-like mass of cells that covers and protects the growing tip of a root.

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SEED ID_____

PLANT RESPONSES TO LIGHT
STUDENTS' WORKSHEET

DAY NUMBER Planned Actual | ACTIVITY AND OBSERVATION | RECORD/MEASUREMENT

Have you ever wondered how seedlings "know" which way to grow to emerge above the soil, or why plants on a windowsill seem to lean toward the light? Downward growth of roots (toward water) and upward growth of the shoot (toward light) are essential for a plant's survival.

OBJECTIVES

To understand the response of seedlings to light of different wavelengths.

PRE-LAB QUESTIONS

1. What is your hypothesis about why seedlings grow upward?
2. An ideal control in a geotropism experiment would be a plant grown without gravity. How could this be done?

REQUIRED EQUIPMENT AND MATERIALS

Light wave length Investigation

Materials

2 lightproof, plastic film canisters from 35-mm film
plastic film sheets---red, green, blue
hand-held paper punch or electric drill and 13/64" drill bit
clear plastic tape and black plastic electrical tape
2-cm square pieces of paper towel
waterproof pen
RCBr seeds

0 ___ LABORATORY ACTIVITY

Phototropism

1. Make a phototropism chamber as follows (Figure 1):
   a. Punch or drill three windows in the sides of the film container 20 to 22 mm from the bottom.
   b. On one of the film cans, tape squares of colored plastic over the windows with clear tape. Cover one window with green film, one with red, and one with blue.
   c. On the second film can tape squares of red colored, blue colored and clear plastic over the holes drilled.
   d. Mark the lids with the waterproof pen to line up the lid with the windows at the same locations each day.
   e. Place a square of wet paper towel in the lid of the film container. The lid becomes the base of the tropism chamber.
2. Place three seeds on the wet paper towels of each chamber. Close the chambers and put them, with the lids at the bottom, under the light bank where all three windows receive uniform light.

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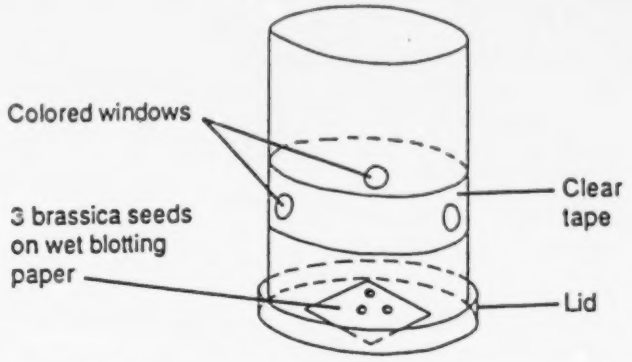
DAY NUMBER Planned Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT

Figure 1. Phototropism chamber



LABORATORY OBSERVATIONS

2 ___ 1. After 48 to 72 hours, open the chamber and observe which way your plants have grown. Which colors did your plants grow toward? First chamber plastic panel plants grow toward_____
Second chamber plastic panel plants grow toward_____

2. What color (wave length) of light does the plant seem attracted to? Remember that the color you see on the colored plastic panels is the color being reflected, not allowed through.
First chamber color of light allowed through panel_____
Second chamber color of light allowed through panel _____

3. What color material would be the most photo effective for greenhouse cover material?
Optimum greenhouse cover material color_____

4. Other than color of light allowed through the plastic, is there any other characteristic of light that might affect a plants photo efficiency?

_____
_____

6. What caused the plants to grow as they did in the phototropism experiment?

_____

7. Describe an experiment you would set up to demonstrate or measure the importance of this other characteristic of light. Make sure you have a control factor for light color.

_____
_____
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NAME_____
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SEED ID_____

PLANT RESPONSES TO GRAVITY
STUDENTS' WORKSHEET

DAY NUMBER Planned Actual | ACTIVITY AND OBSERVATION | RECORD/MEASUREMENT

The response to gravity is known as gravitropism. Both of these responses are thought to be mediated by plant hormones called auxins, which affect cell elongation. These experiments investigate these responses and their causes.

OBJECTIVES
To understand the response of seedlings to gravity.

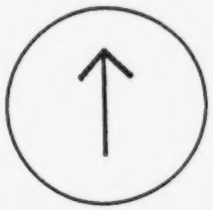
PRE-LAB QUESTIONS
1. What is your hypothesis about why seedlings grow upward?
2. An ideal control in a geotropism experiment would be a plant grown without gravity. How could this be done?

INVESTIGATION I

REQUIRED EQUIPMENT AND MATERIALS
Gravity Investigation
Materials
lightproof, plastic film canisters from 35-mm film
2-cm square pieces of paper towel
waterproof pen
RCBr seeds and 3 to 5 days-old seedlings

0 ___ LABORATORY ACTIVITY
Gravitropism--Experiment A
1. Set up a windowless chamber. Mark the top of the lid with an arrow (Figure 2). Place a 2-mm square of paper towel in the lid and moisten.

Figure 2. Mark top of lid with an arrow.



2. Place three seeds on the paper towel. Close the chamber and place vertically with the lid at the bottom.

LABORATORY OBSERVATIONS
1. After 2 days, observe your seedlings and record your observations in Figure 3. Close the chamber tightly and place the chamber horizontally (Figure 4) with the arrow pointing upward.

Figure 4. Gravitropism chamber.

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DAY NUMBER Planned Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT

2. Examine the seedlings on the third day and record your observations in Figure 3. Replace the chamber horizontally with the arrow pointing upward. Examine the seedlings on the fourth day and record your observations in Figure 3. (The seedlings may now be transplanted to potting mix.)

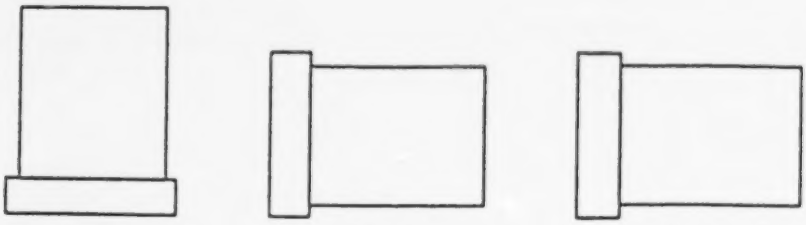

Figure 3. Draw your seedlings after 2,3, and 4 days in the chambers.

LABORATORY ACTIVITIES

Gravitropism---Experiment B

1. Set up another windowless chamber. Mark the top of the lid with an arrow (Figure 2). Place a 2-mm square of paper towel in the lid and moisten.

2. With a sharp instrument, cut off a 3-to 5-day-old seedling at the soil level. Stick the cotyledons to the moistened paper towel(water will hold them in place; Figure 5). Close the chamber and place horizontally with the arrow pointing upward.

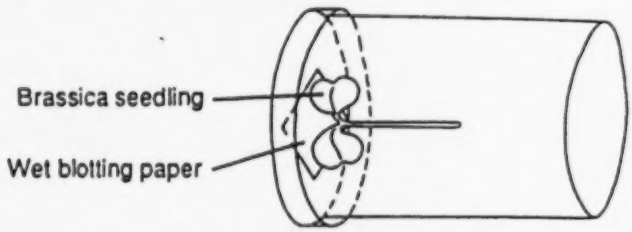

Figure 5. Gravitropism chamber.

LABORATORY OBSERVATIONS

1. Examine the orientation of the hypocotyl after 24 and 48 hours, and after 5 to 7 days. Record your observations in Figure 6. After each examination, close the chamber and place it horizontally with the arrow pointing upward. What is happening at the very tip of the hypocotyl?

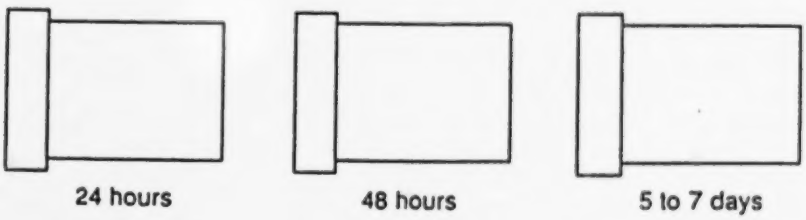

Figure 6. Draw your seedlings after 24 and 48 hours and 5 to 7 days in the chamber.

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DATE_____
SEED ID_____

DAY NUMBER Planned Actual | ACTIVITY AND OBSERVATION | RECORD/MEASUREMENT

LABORATORY OBSERVATIONS

1. What do the following prefixes mean?

   photo--_____

   gravi--_____

   tropism--_____

2. Did the stems and roots grow the way you expected them to in Gravitropism---Experiment A? Explain what you observed.

_____
_____
_____
_____

3. Did the modified seedling grow the way you expected it to in Gravitropism---Experiment B? Explain what you observed.

_____
_____
_____
_____

4. What direction would a seedling grow if a darkened horizontal chamber was slowly, constantly rotated?

_____

5. What do you think these gravimetric responses might have on the use of plants in space exploration projects?

_____
_____

6. Which do you think is the more important factor affecting the direction of plant growth, light or gravity? design an experiment to test your hypothesis.

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NAME_____
DATE_____
SEED ID_____

PLANT RESPONSES TO GRAVITY
STUDENTS' WORKSHEET

DAY NUMBER Planned Actual | ACTIVITY AND OBSERVATION | RECORD/MEASUREMENT

INVESTIGATION II

REQUIRED EQUIPMENT AND MATERIALS
Materials
four quads of 12-to 14-day-old plants.
two light-excluding boxes
fluorescent light bank
protractors

PRE-LAB QUESTIONS
1. Do plants grow upward in response to light or to gravity?

LABORATORY ACTIVITIES
1. With a pen or pencil, number the plants in each quad, 1 through 4.
2. Place a control quad of plants upright under the fluorescent light bank. Place an experimental quad of plants on its side under fluorescent light bank. Place a control quad of plant upright in a light-excluding box. Place the remaining experimental quad of plants on its side inside a light-excluding box.
3. Use a protractor to estimate the angle of the stems (Figure 7) while observing the plants under the lights every half hour (up to 2 hours). Record your observations in Table 1.
4. After 2 hours, remove the plants from the light-excluding boxes. Use a protractor to estimate the angle of the stems and record your observations in Table 1.

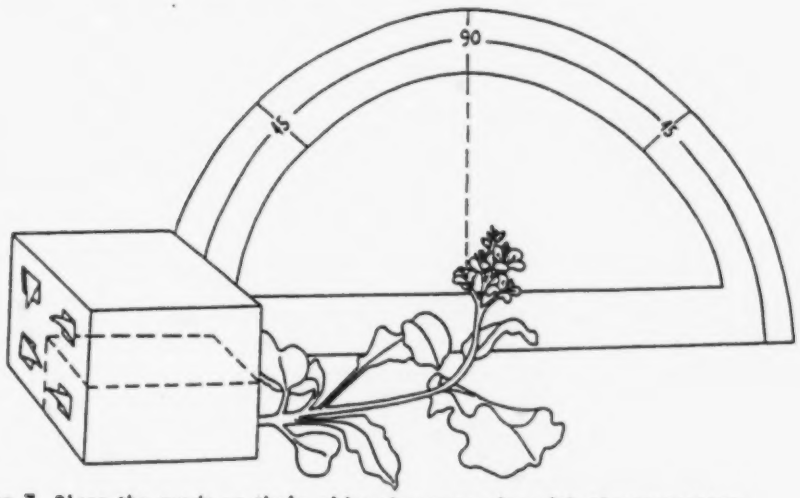

Figure 7. Place the quads on their sides when measuring with the protractor.

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NAME_____
DATE_____
SEED ID_____

DAY NUMBER Planned Actual | ACTIVITY AND OBSERVATION | RECORD/MEASUREMENT

LABORATORY OBSERVATIONS

TABLE 1. Stem Angles.

		Angle of stem after			
Plants in light	plant no.	1/2 Hr	1 Hr.	1.5 Hr.	2 Hr.
Control	1				
	2				
	3				
	4				
Experimental	1				
	2				
	3				
	4				
Plants in dark					
Control	1				
	2				
	3				
	4				
Experimental	1				
	2				
	3				
	4				

1. Describe what has happened to the plants.

* Indicates a word that may be found in the GLOSSARY OF TERMS in the back of the lab sheets.

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DATE_____
SEED ID_____

DAY NUMBER Planned Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT

2. Why did the plants bend?

_____
_____

3. Why didn't you observe the plants in the light excluding box every half hour?

_____
_____

4. Does the stem respond the same way along its entire length? Does this suggest anything about what region is most sensitive to the effects of light or gravity?

_____
_____

5. Which do you think is the more important factor affecting the direction of plant growth, light or gravity? Design an experiment to test your hypothesis.

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NAME_____
DATE_____

DAY NUMBER Planned	Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT
14 thru 16	____ thru ____	FLORAL DEVELOPMENT, COUNTING OPEN FLOWERS AND POLLINATION

We are the beneficiaries of virtually every aspect of plant physiology. We eat their seeds, sprouts, stems, roots, flowers, and fruit. We wear their fibers, petals, and smells. We burns all parts for all reasons. Their roots hold our soils and water in place and their stems and leaves block the wind and sun for us. However, the plant does all these things for the single purpose of setting a flower, making a seed or reproducing itself in some fashion. A motivation that carries a high priority in even our sophisticated life form. If uninterrupted, the plant complete this reproductive cycle while carrying on a lush vegetative life style and still produce seed at the optimum time for species survivability. Interrupt the life cycle, i.e. pasture the cows, mow the grass, and the plant will give up some of it's lush vegetative life style and work instead on reproduction. A plant's gotta do what a plant's gotta do. These laboratory experiences are directed at examining and comparing the floral stages of plant life.

LABORATORY ACTIVITIES

1. Count all open flowers. Remember, new flowers will continue opening at the observable rate of around every eight hours. You need to record the total number of open flowers each day for the next three days. Record your answers below.

ID CODE_____	ID CODE_____
Day___ flower count____ Day___ flower count____ Day___ flower count____	Day___ flower count____ Day___ flower count____ Day___ flower count____
Day___ flower count____ Day___ flower count____ Day___ flower count____	Day___ flower count____ Day___ flower count____ Day___ flower count____

ID CODE_____	ID CODE_____

2. Using the BEE STICKS you made at least a day ago, start pollinating all the open flowers. You will need to do this daily for the next three days. You may have some breeding scheme for mating the plants you have available to you. If that is the case, you need to keep a record of what parent you crossed with what. Remember, the stamen (male) product (pollen) of plant "A" will not be exactly, genetically the same as the Pistil (female) product (ovule). So "A" pollen on "B" Pistil could very possibly a different offspring than "B" pollen on "A" Pistil. Keep an accurate of those crosses in the space provided below. This plant does not readily self pollinate. You will need to employ a special procedure to self pollinate any of your plants. If you are going to attempt a specific program, use one BEE STICK for crossing ONE WAY ONLY, i.e. "A" pollen to "B" Pistil only. Use BEE STICKS one day only then discard or refrigerate for optional experimental use. Use an "X" to indicate a cross breeding and a circled "X" for self pollination.

ID CODE_____	ID CODE_____
Pollen parent_____ Pollen parent_____	Pollen parent_____ Pollen parent_____

* Indicates a word that may be found in the GLOSSARY OF TERMS in the back of the lab sheets.

RCBr LABORATORY WORKSHEET

TEAM MEMBER NAMES

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TEAM NAME_____
DATE_____

BEE ANATOMY AND PLANT POLLINATION TEACHER'S GUIDE

Subject Areas
Bees, their parts and their function in plant pollination

Course Goals
AB11-The student will demonstrate plant breeding techniques

Objectives
To identify Bee parts and their function in plant pollination

Time required
Student Observation occurs in one class period

Materials
For the entire class:
A roll of wide clear adhesive tape.
dissecting stereoscopic microscope

For each student team:
Dead, complete bee body
Tweezers, small forceps
Hand lens or magnifying glass (dissecting stereoscopic microscope if available)

Background

Symbiosis* is the close association of two or more dissimilar organisms. Such associations can be beneficial to both organisms. Associations can be beneficial to both organisms (mutualistic) or detrimental to one (parasitic). Symbiotic relationships among species occur frequently in nature. When the two or more species in a symbiosis evolve reciprocally, in response to each other, they are said to coevolve*. Under close examination each symbiosis stands out as an example of the miraculous complexity which has evolved in our everyday world. The coevolution of brasicas and bees, each dependent upon the other for survival, is such a relationship.

What is a flower? In our eyes it is something to enjoy. For bees and other nectar gathering insects, it is a source of good. For the plant, flowers are vital organs of reproduction containing both male and female gametes. Within each Brassica flower the male and female parts are just millimeters apart so that when pollen from the anthers falls onto the stigma, pollination may occur.

For many brassicas, however, the act of pollination does not insure fertilization and seed formation. Some brassica species contain special recognition compounds, glycoproteins*, which are found within both the stigma and the pollen and are unique to each plant. These compounds enable the plant to recognize "self" pollen and is called self-incompatibility*. In order for fertilization to occur pollen must travel from one brassica plant to the stigma of an entirely different brassica (cross-pollination*). In this way brassicas ensure that their genes will be well mixed through the population.

The pollen itself is heavy and sticky unable to be easily windborne. For brassica plants, bees are marvelously coevolved pollen transferring devices. Bees are members of the insect family Apidae, which are unique in that their bodies are covered with feather-like hairs. The bright yellow flower petals act as both beacon and landing pad for the bees, attracting them to the flower and guiding them to the nectaries. The bee drives its head deep into the flower to reach the sweet liquid (nectar) secreted by the nectaries and brush against the anthers and stigma. Quantities of pollen are entrapped in its body hairs. As the bees work the brassica fields, moving from plant to plant, cross-pollination occurs and genetic information is widely transferred.

Bees depend on the flower for their survival. Sugars in the nectar provide carbohydrates to power flight and life activities. Pollen is the primary source of proteins, fats, vitamins, and minerals to build muscular,
* Indicates a word that may be found in the GLOSSARY OF TERMS in the back of the lab sheets.

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TEAM NAME_____
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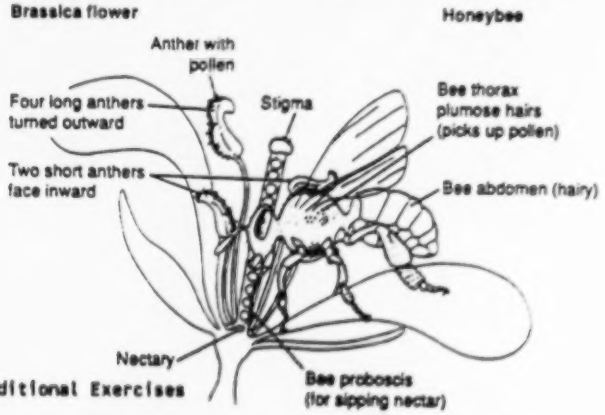
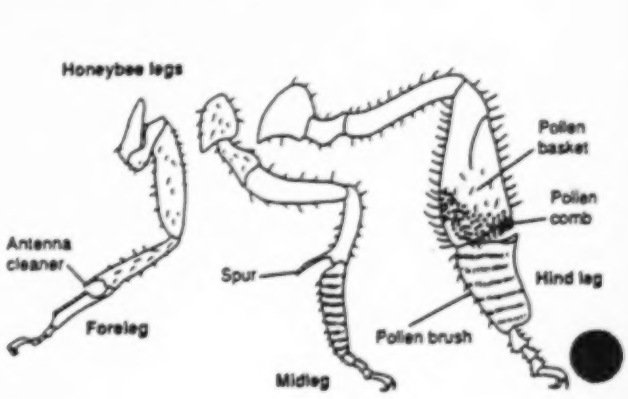
glandular, and skeletal tissues. The average colony of bees will collect 44 to 110 pounds of pollen in a season. It is fed in a partially digested state to the larvae and young emerging bees. Royal jelly, a glandular secretion of the workers, rich in pollen protein is fed to the young larvae and to the queen.

A worker bee foraging for pollen will hover momentarily over the flower as she uses her highly adapted legs for pollen collection. The foreleg is equipped with the antenna cleaner, a deep semicircular notch with a row of small spines. This is quickly passed over the antenna. Using the large flat pollen brushes on the midlegs, the bee quickly brushes the sticky pollen from her head, thorax and forelegs. The special adaptive features of the hind legs. First the pollen captured on the midleg brushes is raked off by the pollen combs onto the pollen press. This press is a deep notch located in the joint just below the pollen basket. Flexing the leg, the bee packs the pollen into the baskets which are enclosed spaces on the upper hindleg formed by a concaved outer surface finger with long curved hairs. When the baskets are filled, the workers bee returns to the hive with her supplies to feed the colony--nectar in her honey stomach, pollen in the baskets. In the process the continuation of a new generation of brassicas is ensured through her pollination activities.





Additional Exercises

1. Perform the laboratory with common house fly and compare answers.

Glossary

Coevolve When the two or more species in a symbiosis evolve reciprocally, in response to each other.

cross-pollination The transfer of pollen from the anther of one flower to the stigma of another.

Glycoproteins special recognition compounds found within both stigma and pollen and are unique to each plant. These compounds enable the plant to recognize "self" pollen. In order for fertilization to occur pollen must travel from one brassica plant to the stigma of an entirely different brassica (cross-pollination)

petal A flower part that is usually colored.

self-incompatibility The mechanism by which the stigma of a flower recognizes the pollen from the same plant and prevents fertilization from taking place.

stamen The part of the flower producing pole, composed of an anther and a filament.

stigma The receptive surface of the pistil to which pollen grains adhere and on which they germinate.

Symbiosis is the close association of two or more dissimilar organisms. Such associations can be beneficial to both organisms.

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RCBr LABORATORY WORKSHEET

TEAM MEMBER NAMES

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TEAM NAME_____
DATE_____

FLOWER ANATOMY STUDENTS' WORKSHEET

DAY NUMBER Planned Actual | ACTIVITY AND OBSERVATION | RECORD/MEASUREMENT

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1 ___

OBJECTIVES

To identify Bee parts and their function in plant pollination

MATERIALS

For the entire class:

A roll of wide clear adhesive tape.
dissecting stereoscopic microscope

For each student team:

Dead, complete bee body
Tweezers, small forceps
Hand lens or magnifying glass (dissecting stereoscopic microscope if available)

LABORATORY ACTIVITY

1 ___

1. Select a fresh looking but dead bee from those available by your instructor.
2. Examine the Bee in detail with your naked eyeball. See if you can match up body parts on your bee with those identified on the provided picture.
3. Examine the bee in detail under the stereoscopic microscope or hand lens.
4. Answer questions 1 thru 5 before continuing with the rest of the laboratory Activities.
5. Position the bee in such a fashion that you can closely examine the wings, legs and thorax. answer questions 6 thru 10 in the Laboratory Observations section.
6. Place a piece of clear adhesive tape on the table and use it to hold the body parts of the bee as you dissect it. Dissect and identify the following body parts. Make sure you label the requested body parts. Head, thorax, wings, foreleg, midleg, lindleg, abdomen, pollen sack, pollen brush.
7. Place a second piece of clear adhesive tape gently over the top of the bee parts tape created in Laboratory Activity number 6.
8. Use the tape display of flower parts just created to complete the assignment in Laboratory observation number 11.

LABORATORY OBSERVATIONS

1. Identify the three major body segments of the bee body.
   a._____
   b._____
   c._____

2. Examine the head, identify the proboscis and determine what it is designed to do and why.
   _____
   _____

3. How many legs does the bee have? _____

4. What body part do the legs attach to? _____

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RCBr LABORATORY WORKSHEET

TEAM MEMBER NAMES

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TEAM NAME_____
DATE_____

DAY NUMBER Planned Actual | ACTIVITY AND OBSERVATION | RECORD/MEASUREMENT

5. The antenna cleaners on the front legs of the bee clean the antennas. Why should clean antenna be so important to bees?

_____
_____

6. How many wings does a bee have?_____

7. Describe the surface of the Thorax?

_____
_____

8. Describe the surface of the Pollen sack.

_____
_____

9. Why has nature designed these body surfaces the way they are. Be Specific.

_____
_____

10. What guarantee is there that the bees will come in contact with the pollen on the flower.
a._____
b._____
c._____

11. Attach your completed Bee parts display tape to the space provided below and label the parts requested in Laboratory activity number 6.

12. FOR EXTRA CREDIT. Draw a picture of a complete Honeybee on the back of this lab sheet and label the parts YOU consider important to the pollination process.

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NAME_____
DATE_____

ID CODE_____ ID CODE_____

DAY NUMBER Planned	Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT
17	___	FLORAL DEVELOPMENT, POLLINATION AND BUD REMOVAL	

These plants have been selected and bred for many years to flower quickly and have a short, rapid life cycle. That doesn't mean the only genes present in their Genome* are Rapid cycle genes. Genetic diversity through recessive genes or mutation can at any time produce offspring that have few if any of the rapid cycling characteristics. Your breeding program needs to demonstrate plant breeding methods that help insure emphasis of the rapid cycling characteristics as well as those specific characteristics you are selecting for. This laboratory exercise marks the end of the breeding (pollination) stage and by bud removal helps guarantee no late opening flower genes are passed on to the next generation by eliminating the later opening flowers.

LABORATORY ACTIVITIES

1. Pollinate all flowers for the final time. Make sure you observe all technical restrictions set up in the breeding program you set up in the previous lab.
2. Using a sharp blade, scissors, or pinchers remove all buds, unopened flowers, side shoots without pollinized flowers and the shoot apex. This activity will help focus all plant's energies on the fertilized flowers and the pods that will develop from them.
3. Continue to remove all new flower buds that may develop after this date.

LABORATORY OBSERVATIONS

1. In the space provided below record the number of pollinized flowers remaining on each plant.

ID CODE_____ ID CODE_____

No of Pollinized flowers_____	No of Pollinized flowers_____
No of Pollinized flowers_____	No of Pollinized flowers_____

ID CODE_____ _____ ID CODE_____

2. Now that the remaining flowers are all pollinized, what changes do you expect to see in the flowers?

3. Will a part of the flower develop in to the seed pod or will a totally new vegetative growth become the seed pod?

4. If any more flowers appear, where would you expect them to develop from on the plant?

ARRANGE CLASS TEAM LABS TO DEMONSTRATE SELF POLLINATION TECHNIQUES.

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NAME_____
DATE_____

DAY NUMBER Planned	Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT
18 thru 35	____ thru ____	INCUBATION, SEED AND POD DEVELOPMENT Pollination is followed by Fertilization*. With the conception* of this potential life comes the responsibility of providing the mother plant with a very consistent supply of the necessities of life. She in turn will provide the incubating seed in her pods with the microenvironment necessary for their continued development. The osmacoat fertilizer originally applied will continue it's timed release. The 24 hour a day exposure to the growth lights must continue through day 40. The water level of the reservoir must be maintained as usual through day 36. Any variation in this routine will result in a longer incubation period and or fewer seeds of lower germination potential. Since you have created an artificial environment, the responsibility to maintain it rests with you. LABORATORY ACTIVITIES 1. Continue to remove new flower buds. 2. Count the number of elongating seed pods present on day 25. 2. Check irrigation reservoir level daily. 3. Make sure the plant growth lights remain on 24 hours a day. 4. Keep the growth chamber area temperature at the same 60 to 80 Degrees F. LABORATORY OBSERVATIONS 1. For sanity's sake, consolidate all your measurements from days 1 thru the present in the space provided below.	

ID CODE_____ ID CODE_____

Day of emergence____ Day transplanted____ No. of leaves_____ lngth.2nd.true leaf_____ plant height_____ Day___ flower count____ Day___ flower count____ Day___ flower count____ Pollen parent_____ No of Pollinized flowers_____ No of seed pods set____ No of seed pods harvested____ No of seed harvested____	Day of emergence____ Day transplanted____ No. of leaves_____ lngth.2nd.true leaf_____ plant height_____ Day___ flower count____ Day___ flower count____ Day___ flower count____ Pollen parent_____ No of Pollinized flowers_____ No of seed pods set____ No of seed pods harvested____ No of seed harvested____
Day of emergence____ Day transplanted____ No. of leaves_____ lngth.2nd.true leaf_____ plant height_____ Day___ flower count____ Day___ flower count____ Day___ flower count____ Pollen parent_____ No of Pollinized flowers_____ No of seed pods set____ No of seed pods harvested____ No of seed harvested____	Day of emergence____ Day transplanted____ No. of leaves_____ lngth.2nd.true leaf_____ plant height_____ Day___ flower count____ Day___ flower count____ Day___ flower count____ Pollen parent_____ No of Pollinized flowers_____ No of seed pods set____ No of seed pods harvested____ No of seed harvested____

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NAME_____
DATE_____

ID CODE_____ ID CODE_____

DAY NUMBER Planned	Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT
36	___	PLANT/SEED POD DRY DOWN You have probably noticed some changes in the mother plant over the past 20 days. As the seeds pods rapidly developed the plant probably began to appear more spindly or less lush and growthy green. Perhaps the lower leaves showed some signs of desiccation or drying up. There are a number of other changes you probably noticed and most if not all of them are caused by the plant investing all of it's efforts and life force into the act of reproducing itself. In annual* plants this is a life consuming activity with or without our contribution as the plant breeder. LABORATORY ACTIVITY 1. Remove your plants from the water mat and irrigation reservoir. 2. Allow the seed pods to dry on the plants for 5 days. If you want to accelerate the drying process try the following process. Cut off the seed pods. Place the pods in a brown paper bag. Place the paper bag of your pods on top of the growth lights with the lights on. leave the bag there for three days.	

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NAME_____
DATE_____

DAY NUMBER Planned	Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT
40	____	HARVESTING THE SEEDS	

The time has come to collect and preserve the makings of the next generation of this life form. It is a simple process in nature. Since we are plant breeders needing to learn more about the heritable characteristics of this plant, we are going to complicate the process. Nature is perfectly satisfied to take millennium to make it's changes. As humans we live a little faster pace. Faster change requires more knowledge, precision, and attention to detail. This lab's exercise is pointed at that effort.

LABORATORY ACTIVITY

1. Using a sharp blade, scissors, nippers, etc. remove the seed pods from your plants. Keep the pods of each plant separate for accountability.
2. Record the data about each plant in the space provided below. Detail is essential.
3. After recording the required pod data, save the number of whole pods requested by instructors
4. As you prepare to remove the seed from your pods remember to keep the pods from each plant separate so you can get an accurate seed count per plant. You can get a reasonable seed count of the unopened pods by holding the pods up to a bright light and counting the shadows of the seeds in the pods.
5. Separate the seed from the pods by gently rolling the dry pods between your hands held over a collecting pan or sheet of paper.
6. Remove the pod trash from your seed. Be careful not to throw out seed with the pod debris.
7. Record the required seed data in the space provided below.
8. Seed from each plant or type should be stored separately in screw cap containers with a silica gel desiccant capsule. The seed containers should be stored at 4 Degrees C (45 degrees F) if it is going to be held for more than 4 to 6 months.
9. A description of the seed's pods and parents should be permanently recorded for future breeding projects. Each seed bottle should be coded to that description.

LABORATORY OBSERVATIONS

1. Record your Seed pod information in the space provided below.

ID CODE_____	ID CODE_____
No. of pods_____	No. of pods_____
Max. pod length cm_____	Max. pod length cm_____
Min. pod length cm_____	Min. pod length cm_____
Ave. pod length cm_____	Ave. pod length cm_____
Max. no. seeds per pod_____	Max. no. seeds per pod_____
Min. no. seeds per pod_____	Min. no. seeds per pod_____
Ave. no. seeds per pod_____	Ave. no. seeds per pod_____
Total no. of seeds_____	Total no. of seeds_____
No. of pods_____	No. of pods_____
Max. pod length cm_____	Max. pod length cm_____
Min. pod length cm_____	Min. pod length cm_____
Ave. pod length cm_____	Ave. pod length cm_____
Max. no. seeds per pod_____	Max. no. seeds per pod_____
Min. no. seeds per pod_____	Min. no. seeds per pod_____
Ave. no. seeds per pod_____	Ave. no. seeds per pod_____
Total no. of seeds_____	Total no. of seeds_____
ID CODE_____	ID CODE_____

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NAME_____
DATE_____

DAY NUMBER Planned	Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT
40	___	HARVESTING THE SEEDS LABORATORY OBSERVATIONS	

2. Chart your pod and seed data against the results of four other classmates. Use the charts provided below to compare your data.

Place a "N" on the graph to identify the NUMBER of pods harvested per plant.
Place a "L" on the graph to identify the LONGEST pod harvested from each plant.
Place a "S" on the graph to identify the SHORTEST pod harvested from each plant.
Place a "A" on the graph to identify the AVERAGE POD LENGTH of those harvested.

IDENTITY OF GRAPHED PLANTS

ID.no.	Identity (ID nos. 1 thru 4 should be your plants)
____	_____
____	_____
____	_____
____	_____
____	_____
____	_____
____	_____
____	_____
____	_____
____	_____
____	_____
____	_____
____	_____
____	_____
____	_____

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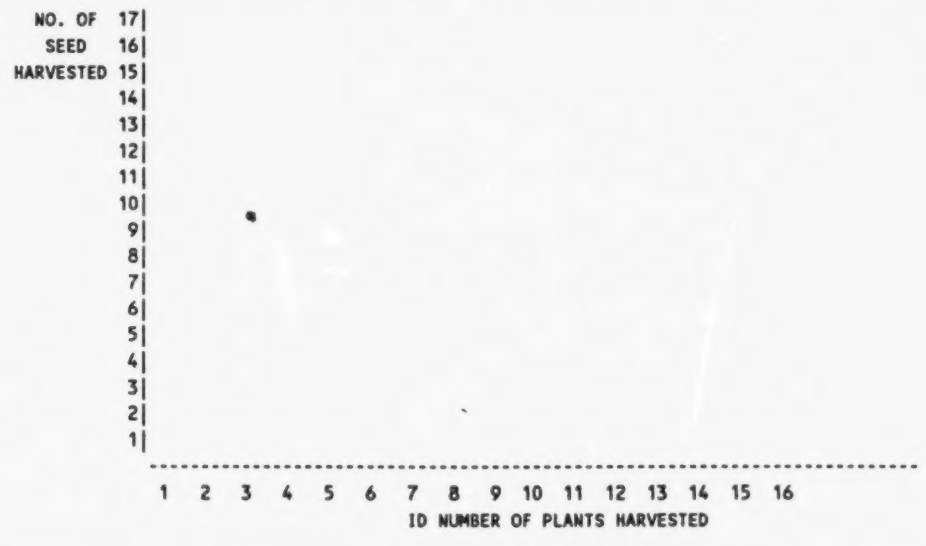
NAME_____
DATE_____

____ _____

DAY NUMBER Planned	Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT
40	____	HARVESTING THE SEEDS LABORATORY OBSERVATIONS 3. Chart your pod and seed data against the results of four other classmates. Use the charts provided below to compare your data. Place a "T" on the graph to identify the TOTAL NUMBER of seeds harvested. Place a "M" on the graph to identify the MAXIMUM SEEDS per pod harvested from each plant. Place a "F" on the graph to identify the FEWEST SEEDS per pod harvested from each plant. Place a "A" on the graph to identify the AVERAGE SEEDS per pod harvested.	



IDENTITY OF GRAPHED PLANTS

ID.no.	Identity (ID nos. 1 thru 4 should be your plants)
____	_____
____	_____
____	_____
____	_____
____	_____
____	_____
____	_____
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____	_____
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NAME_____
DATE_____

DAY NUMBER Planned	Actual	ACTIVITY AND OBSERVATION	RECORD/MEASUREMENT
42	___	LABORATORY REPORT FORMAT	

You've invested a lot of effort into laboratory activities, observations and recorded data. It would be a shame to end the experiment without pulling all this information together and draw a few conclusions. This final exercise provides an outline of both form and content which must be followed for maximum credit. There is a set of report headings and a sequence for them that must be followed. There is another set of key words that must be used correctly in context if the report is to cover the all the important aspects. There is a 3 TO 5 PAGE limit since this report is not graded by the pound. Like all important research, there is a deadline for report completion. The world, or at least your instructor, is anxiously waiting to find out what you have learned. Read on for the particulars we are interested in. NEATNESS COUNTS, IF I CAN'T READ IT I CAN'T GRADE IT.

LABORATORY REPORT HEADINGS

1. LABORATORY ACTIVITIES (30% of the report value)
   In this portion of the report you need to describe the sequence of events you performed or were performed for you in the completion of the experiment. It is here that you describe the day to day things you did in this experiment. Your notes should be a tremendous help in writing this chronicle, assuming you kept them current. The most common order to report these activities in is chronological (time of event) order. This is not the only order you can follow, but whatever order of presentation you choose should be a logical sequence that is easy for the reader to follow. Write the REPORT HEADING before of this section.

2. LABORATORY OBSERVATIONS (30% of the report value)
   This portion of the report is used to present what you saw, measured and or experienced. What happened as a result of what you did. this information needs to be presented in the same order as you selected above. Restrict your report to just those things that you observed or experienced, things that happened. The next portion of the report will concern itself with why it happened or you think it happened. Write the REPORT HEADING before of this section.

3. LABORATORY CONCLUSIONS (20% of the report value)
   What did you learn from this experiment? What did you prove to yourself, the world, your instructor? How does the subject of this experiment function based on your observations? Would you venture any general statements concerning the subject based on your activities and observations? It is in this portion of the report that you finally get to express yourself and share informed opinions based again on your observations and experiences. Strut your stuff! How did all this experience broaden your personal experience. Write the REPORT HEADING before of this section.

LABORATORY KEY WORDS (20% of the report value)

Seed pod	Seed	RCBr	Seed Coat	Shriveled
Placenta	Correlation	Heritable	Receptacle	Stigma
Osmacoat	Potting mix	Wicks	Water mat	Reservoir
Media	Cotyledons	Hypocotyl	Tap root	Leaves
Dicotyledon	Seedlings	Transplant	Photosynthesis	Respiration
True leaf	Flower	Anther	Pistil	Stigma
Style	Ovary	Pollen	Bee stick	Vegetative growth
Pollination	Fertilization	Desiccation	Harvest	Comparative graph data

* Indicates a word that may be found in the GLOSSARY OF TERMS in the back of the lab sheets.

GLOSSARY OF TERMS

abscisic acid A plant hormone involved in leaf drop and seed dormancy.

accessory pigment A pigment that captures light energy and transfers it to chlorophyll a.

active transport The pumping of a substance across a cellular membrane from a point of lower concentration to one of higher concentration. Active transport requires energy.

allele One of the two or more alternative forms of gene occupying the same locus on a particular chromosome or linkage structure and differing from other alleles at the locus at one or more mutational sites.

alternation of generations A reproductive cycle in which a haploid (n) phase, the gametophyte, gives rise to gametes which, after fusion to form a zygote, germinate to produce a diploid (2n) phase, the sporphyte. Cells within the sporphyte undergo meiosis to produce spores which give rise to the new gametophyte, thus completing the cycle.

amphidiploid Having two diploid sets of chromosomes, each derived from a different species.

amyloplast A colorless plastid that stores starch.

angiosperm A plant whose seeds are borne within an ovary (fruit).

annual A plant in which the entire life cycle is completed in a single growing season.

antenna cleaner A semicircular structure located on the foreleg of the honey bee, used to collect pollen from the antenna.

anther The pollen-bearing portion of a stamen.

anthocyanin A water-soluble blue, purple, or red pigment found in the vacuole of the plant cell.

Antipodals Three cells of the mature embryo sac located opposite the micropyle.

apex The highest point, pointed end, the tip

Apical dominance Influence of terminal bud in inhibiting in the growth of lateral buds.

apical meristem The area of undifferentiated plant tissue at the tip of the root or shoot from which new cells arise.

asexual reproduction A type of reproduction that does not involve the union of gametets.

auxin A growth hormone which influences cell elongation and is involved with geotropic and phototropic responses. In unequal amounts, auxin causes a curvature of the tissue in stem and roots by causing cell to enlongate differentially.

biennial A plant requiring two growing seasons to complete its life cycle. Vegetative growth occurs the first year and flowering and fruiting occur during the second year.

blade The expanded, flattened part of a leaf or petal (also called lamina).

breed true To produce a self-pollinated plant whose offspring are identical to itself (see segregation).

bud An undeveloped shoot (A shortened, immature section of a stem.)

bud pollination Transfer of pollen before buds open into flowers.

buffer A substance capable of maintaining the relative concentrations of hydrogen and hydroxyl ions in a solution by neutralizing acids or bases.

calyx Sepals, collectively.

carbohydrate An organic compound consisting of a chain of carbon atoms to which hydrogen and oxygen are attached in a 2:1 ratio.

carbon fixation The conversion of carbon dioxide and water into organic compounds during photosynthesis.

carpel A structure in angiosperm that encloses one or more ovules.

cell The structural unit of living organisms.

cell wall The rigid outermost layer of a plant cell.

chlorophyll The green pigment complex in plant cells necessary for photosynthesis.

chloroplast A chlorophyll-containing organelle in green plants where photosynthesis occurs.

chlorosis Loss or reduced development of chlorophyll causing yellowing or blanching of leaves.

chronologically Arranged in order according to time of event

conception Cause to begin life in. The beginning of some process.

coenzyme A small molecule associated with some enzymes and essential for their activity.

correlation A mutual relationship or connection.

cortex A tissue region of a stem or root bounded externally by the epidermis and internally by the vascular system.

cotyledon A primary embryonic leaf; generally stores food in dicotyledons and absorbs food in monocotyledons.

cotyledonary node The part of the stem where the cotyledons are attached.

cross-pollination The transfer of pollen from the anther of one plant to the stigma of another.

cuticle The waxy, protective external covering of the leaf.

cytoplasm The protoplasm of the cell excluding the nucleus.

dehiscence The opening of an anther, fruit, or other structure to permit the escape of reproductive bodies.

dicotyledon A plant whose embryo has two cotyledons; a dicot.

differentially permeable membrane A membrane through which substances diffuse at different rates.

diffusion The movement of a substance from an area of higher concentration to an area of lesser concentration as a result of random movement.

diploid Having two sets of chromosomes; the 2n number charerteristic of the sporophyte generation.

dominance Refers to the expression of genetically controlled characters (phenotypes) and their corresponding alleles when they are in the heterozygous condition. Dominance and recessiveness are not properties of the genes per se, but the result of the action of the genetic locus in question within the total reaction system of a particular genotype. Complete dominance and complete recessiveness are the extreme cases between which all transitional degrees of expression are possible.

dominant A gene that exerts its full phenotypic effect regardless of its allelic partner, thus masking the partner's effect.

dormancy A condition of arrested growth in which the plant (or its parts) does not begin to grow without special environment cues.

double fertilization The union of the egg and sperm resulting in a zygote and the simultaneous union of the second male gamete with the polar nuclei resulting in the 3n endosperms.

emasculation The removal of the stamen to prevent the possibility of self-pollination.

embryo A young sporophytic plant before the start of germination in seed plants.

embryogenesis The development of the embryo from the zygote.

embryo sac The female gametophyte of angiosperms; an eight-nucleated, seven-celled structure containing one egg cell, two synergids, and three antipodals, and the endosperm mother cell (with two nuclei).

endosperm Polyploid tissue containing stored food; formed by the union of the two polar nuclei and one male nucleus; stored food is digested by the growing sporphyte.

epicotyl The upper portion of the axis of an embryo of a seedling, above the cotyledons and below the next leaves.

epidermis The outermost layer of cells covered with a cuticle to help prevent water loss.

eukaryotic Having cells with a membrane-bound nucleus, membrane-bound organelles, and chromosomes in which DNA is associated with proteins.

fertilization to make fruitful by introducing the male germ cell, to impregnate, pollinate.

F 1 generation The offspring produced by crossing two true-breeding plants; the first filial generation.
fertilization The union of an egg (n) and a sperm (n) to form a zygote (2n).

filament The stalk of the stamen bearing the anther.

flower The reproductive structure of angiosperms.

fruit The mature, ripened ovary containing the seeds in angiosperms.

gamete A mature, functional haploid cell whose nucleus fuses with that of another gamete of opposite sex to form a zygote.

gametophyte The gamete-producing plant.

gene A sequence of nucleotides along a molecule of DNA (RNA in some viruses) that makes up a unite of inheritance.

genotype 1. The genetic constition in respect to the alleles at one genetiac locus. 2. The sum of the genetic information (genes) contained in chromosomes (linkage groups) of pro-and-eukaryotes. The genotype determines not a unique phenotype but a range of phenotypic expression referred to as the individual's reaction norm.

genome One complete haploid set of chromasomes of an organism

germ cell The reproductive cell which, when united with a germ cell of the opposite sex, develops into a new individual.

germination The beginning of growth by a seed.

gibberellins A group of growth-regulating substances best known for increasing the elongation of stems.

gravitropism The response of a shoot or root to the pull of the earth's gravity.

guard cells Pairs of specialized epidermal cells surrounding a stoma; changes in turgor pressure of gaurd cells causes opening and closing of the stoma.

haploid The state in which each chromosome is represented once.

heterosporous Having spores of two kinds, usually designated as microspores and megaspores.

Heterozygous In dipolodis organisims the condition of having different alleles at one or more loci (genes) in homologous chromosome segments, in contrast to homozygous, having identical alleles at these loci.

homologous chromosomes Chromosomes that associate in pairs in the first stage of meiosis; each member of the pair is derived from a different parent.

hormone A chemical substance produced, usually in minute amounts, in one part of an organism and transported to another part of the same organism, where it has a specific effect.

hybrid A plant resulting from a cross between two pure-breeding lines.

hypocotyl The portion of an embryo or seedling situated between the cotyledons and the radicle.

hypocotyl-root axis The embryo axis below the cotyledon(s) consisting of the hypocotyl and the apical meristem of the radicle.

incomplete dominance The condition that results when two different alleles together produce an effect intermediate between the effects of the same two genes in a homozygous condition.

incomplete flower A flower lacking either sepals, petals, stamens, or pistil.

independent assortment The normally random distribution of alleles during meiosis.

integument The outermost layer of tissue enveloping the nucleus of the ovule; develops into the seed coat.

internode The region of a stem between two successive nodes (points where leaves are attached).

lamina See blade.

lateral meristem Cells responsible for increased growth in diameter of a plant.

locus The position of a gene on a genetic map. Allelic genes are situated at identical loci in homologous chromosomes.

mass pollination The random transfer of pollen from the anther of a flower to the stigma of any flower of related or unrelated plants.

megagametophyte The female gametopyte in heterosporous plants; located within the ovules of seed plants.

megaspore A haploid spore that develops into a female gametophyte in a heterosporous plant.

megaspore mother cell A diploid cell in which meiosis will occur, resulting in the production of four megaspores.

meiosis The reproduction of chromosome number from diploid to haploid in which segregation of genes occurs and gametes or spores are formed.

meristem The undifferentiated plant tissue from which new cells arise.

microgametophyte The male gametophyte in a heterosporous plant.

micropyle The opening in the integument through which the pollen tube usually enters.

microspore A spore that develops into a male gametophyte; a pollen grain.

microspore mother cell A diploid cell in which meiosis occurs, resulting in four microspore.

mitosis The segregation of duplicated chromosomes in a cell nucleus preceding cell division.

monocotyledon A plant whose embryo has one cotyledon; a monocot.

mutant Any heritable variation from the wild type that is the result of a mutation.

natural selection A process that occurs in nature whereby strong and well-adapted organisms.

nectary A gland located in an angiosperm flower that secretes a sugary fluid which pollinators (birds and insects) use as food.

node the part of a stem where one or more leaves are attached.

osmosis The movement of a substance from an area of higher concentration to an area of lower concentration across a permeable membrane.

ovary The enlarged basal portion of the pistil housing the ovules.

ovule A structure in a seed plant containing the female gametohpyte with egg cell and surrounded by one or two integuments.

pH The symbol for the relative concentration of hydrogen ions in a solution; a pH of 7 is meutral, less than 7 is acidic, and more than 7 is alkaline.

pedicel The stalk of an individual flower.

perennial A plant that gives year and usually produces reproductive structures in two or more years.

petal A flower part that is usually colored.

petiole The stem-like region of the leaf that connects the leaf blade to the stem.

phenotype The obserable properties (structural and functional) of an organism, produced by interaction of the organism's genetic potential (its genotype) and the environment. The term phenotype can be applied either to the totality of expressions of the genotype or to only a part (i.E., to particular characters of traits). The phenotypic range of expression is referred to as its reaction norm.

phloem Food-conducting tissue in vascular plants; carries food produced in the leaves to other plant parts.

photolysis The splitting of water in the light-dependent processes of photosystem II during photosynthesis.

photosynthesis The conversion of light energy to chemical energy; the manufacture of carbohycdrates (sugar) and oxygen by plants in the presence of light and chlorophyll.

photosystem A unit of chlorophyll and other pigment molecules embedded in the thylakoids of chloroplasts and involved with the light-requiring reaction of photosynthesis.

phototropism Growth in which the direction of the light is the determining factor; turning or bending in response to light.

pigment Substance that absorbs light, often selectively.

pistil The central organ of a flower typically consisting of an ovary, style, and stigma.

placenta that part of the lining of the ovary that bears the ovules and provides an avenue for both fertilization and nutrition in embryonic development.

plant wilt Limpness of a plant from a greater loss of moisture by transpiration than the rate of absorption by root hairs.

plumule The first bud of an embryo; the portion of the young shoot above the cotyledons.

polar nuclei Two nuclei, one derived from each end (pole) of the embryo sac, which become centrally located; they fuse with a male nucleus to form the primary endosperm nucleus.

pollen A collective term for pollen grains.

pollen basket An enclosed space lined with long curved hairs in each of the upper hind legs of the bee; used to transport pollen from the flower back to the hive.

pollen brush Large flat structures located on the mid legs of the bee used to collect pollen from the head, thorax, and forelegs.

pollen comb Structures on the hind legs of the bee used to rake pollen collected on the mid leg brushes onto the pollen press.

pollen grain The mature male gametophyte of angiosperms.

pollen parent Plant selected to provide pollen for fertilization (see seed parent) and usually referred to as the male parent.

pollen press A bee, notched structure located in the joint just below the pollen basket on the hind leg of the bee and used to press the pollen collected into the basket.

pollen tube A tube formed after germination of the pollen grain; carrier the male gametes into the ovule.
pollination The transfer of pollen from the anther to the stigma.

primary endosperm nucleus The result of the fusion of a sperm nucleus and the two polar nuclei.

proplastid A self-reproducing organelle which develops into a plastid.

protoplasm A general term for the living substance of all cells.

quantitative Capable of being measured.

radicle Embryonic root.

Rapid cycling Brassica rapa B.rapa cultivar selected for short duration to flowering, fast seed maturation, no seed dormancy, small plant size and high female fertility.

RCBr See Rapid Cycling Brassica rapa

receptacle That part of the axis of a flower stalk that bears the floral organs.

rescessive A gene whose phenotypic expression is masked by its dominant allele.

recessiveness The absence of expression of genetically controlled characters and their corresponding alleles when they are in the heterozygous condition.

root The descending axis of a plant, usually below ground, that anchors the plant and absorbs and conducts water and minerals.

root cap A thimble-like mass of cells that covers and protects the growing tip of a root.

root hairs Tubular outgrowths of the root which absorb nutrients and water for the plant.

rosette A plant that grows very compactly at soil level with the leaves fanning out into a rosette pattern.

sap The fluid contents of xylem or phloem.

seed In seed plants, a structure formed by the maturation of the ovule following fertilization.

seed coat The outer layer of the seed developed from the integuments of the ovule.

seed parent The plant selected to provide the ovule for fertilization-producting seed (see pollen parent); usually referred to as the female parent.

seedling A young sporophyte that has developed from a germinating seed.

having alternation of generations.

stamen The part of the flower producing pole, composed of an anther and a filament.

stem The part of the axis of a vascular plant that is above ground.

stigma The receptive surface of the pistil to which pollen grains adhere and on which they germinate.

stoma (pl. stomata) A minute opening border by guard cells in the epidermis of leaves and stems through which gases (air) and water vapor passes.

style The slender column of tissue arising from the top of the ovary through which the pollen tube grows.

succulent A plant with fleshy, water-storing stems or leaves.

synergids Two cells lying close to the egg in the mature embryo sac of the ovule of an angiosperm.

test cross A cross of a dominant with a homosygous recessive; used to determine whether the dominant is homozygous or heterozygous. If two or more genes are involved, the testcross is used to determine the likage relationship between the different genes.

tetrad A group of four spores formed from a spore mother cell by meiosis

thorax The middle section of the body of an insect (arthropod) to which the legs and wings are attached.

transpiration Movement of water, food, and nutrients within plants.

translocation The loss of water, food, and nutrients within plants.

triploid Having three sets of chromosome in each each cell (3n).

tropism A response to an external stimulus in which the direction of the movement or growth is changed.

tube cell The cell that develops into the pollen tube in a male gametophyte (pollen grain) of a vascular plant.

turgor pressure The pressure within the cell resulting from the movement of water in the cell.

variables environmental or biological factors that tend

segragation In genetics, the separation of allele pairs from one another and their distribution to different cells (usually at meiosis) observed only in heterozygous genotypes.

self incompatibility The mechanism by which the stigma of a flower recognizes pollen from the same plant and prevents fertilization from taking place.

self pollination The transfer of pollen from the anther of a flower to the stigma of the same flower or of another flower on the same plant; usually referred to as "selfed."

semipermeable membrane A membrane permeable to water but not to solutes.

sepal One of the outermost flower structures which usually encloses the other flower parts in the buds.

sexual reproduction In plants, the union of a male and a female germ cell resulting in the formation of the seed.

shoot The above-ground portion of a vascular plant, such as the stem and leaves.

sibling pollination The cross-pollination of two or more plants arising from the same parents.

silique Dry, dehiscent fruit characteristic of the mustard family; the valves split from the bottom, leaving the placentae with the false partition stretched between.

species Usually the smallest unit of classification; includes individuals which can breed which each other, produce viable offspring, having the same chromosome number, and share a common gene pool.

sperm A mature male sex cell or gamete, usually more motile and smaller than the female gamete.

spongy layer A leaf tissue composed of loosely arranged, chloroplast-bearing cells where most food manufacture occurs.

spore A haploid (n) reproductive cell, capable of developing into an adult without fusion with another cell.

spore mother cell A diploid (2n) cell that undergoes meiosis and produces four haploid cells (sores).
sporophyte The spore-producing plant in species

to change or deviate from current conditions or type.

variation The differences that occur within the offspring of a particular species.

variegated A plant with yellow or white blotches or streaks on the green leaves and stems, as well as on flower buds and flowers.

vascular bundle Plant tissue that contains xylem and phloem.

vein A vascular bundle forming a part of the framework and supporting tissue in the leaf.

vernalization Inducing the formation of flowers by exposing to a cold treatment.

weed Usually wild plant not valued for its use or beauty and regarded as hindering the growth of useful plants.

wild type The phenotype that is predominant in the majority of individuals of a species in the natural environment, chosen to be the standard for comparing other phenotypes.

xylem The water and mineral-conducting tissue in vascular plants.

zygote The diploid (2n) cell resulting from the union of the male and female garmetes.

Fertilization and Seed Development
Background Information for the Teacher

After pollination, each compatible pollen grain adhering to the stigma sends a tube through the style. This tube carries two male gametes (sperm cells) to the ovule, where the egg and other cell nuclei are contained in he embryo sac. One sperm unites with the egg cell producing a zygote which becomes the embryo. The second sperm unites with the diploid fusion nucleus forming the triploid endosperm, the food source of the developing embryo. This process is known as double fertilization. Endosperm resulting from the union of one of the two male gametes with the fusion nucleus grows mainly as noncellular tissue, filling the enlarging ovules. The embryo's development is then nourished by the endosperm. Within 2 to 3 days after fertilization, the pistil enlongates and swells to become the seed pod. The sepals and petals wither and drop off, having completed their functions.

During days 17 to 35 in the Wisconsin Fast Plants tm growth cycle, the ovules develop into seeds. The embryos go through a series of developmental stages, called embryogenesis, and enlarge, filling the space occupied by the endosperm. Through the development of seeds, the plant packages its new generation (embryos) to survive until favorable growth conditions promote germination. As the seed matures, the walls of each ovule develop into a protective seed coat and the entire ovary becomes a fruit (seed pod). Ovules mature into seeds in 20 days.